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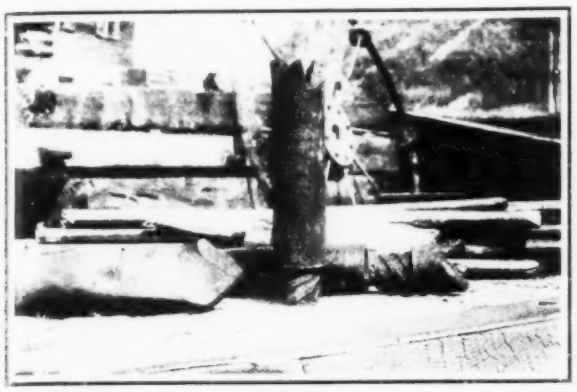
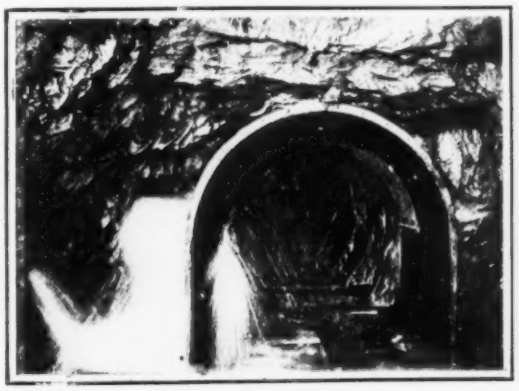


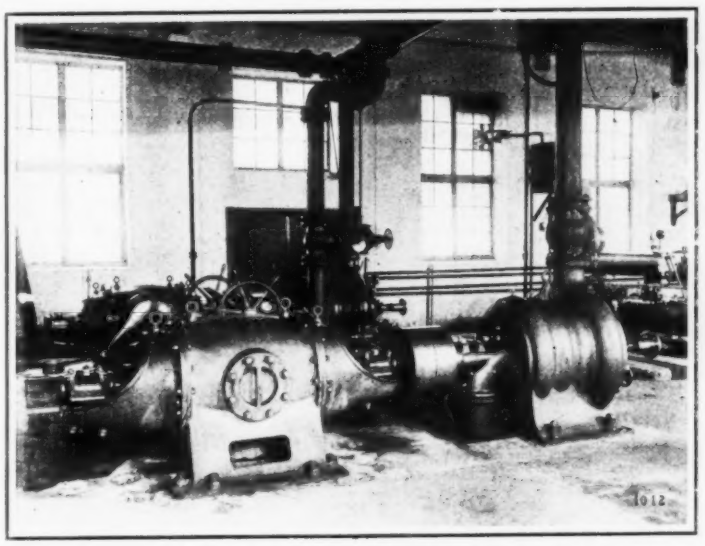
Tubular Rock Drills Employed in Drilling the Tunnel. A Used-up Drill Stump is Shown.

Baron Hugo von Kager, the Engineer-in-Chief of the Work on the Swiss Side.



Iron Shield for Temporarily Shutting Out a Spring. The Force of the Water Has Torn a Large Hole in the Metal.

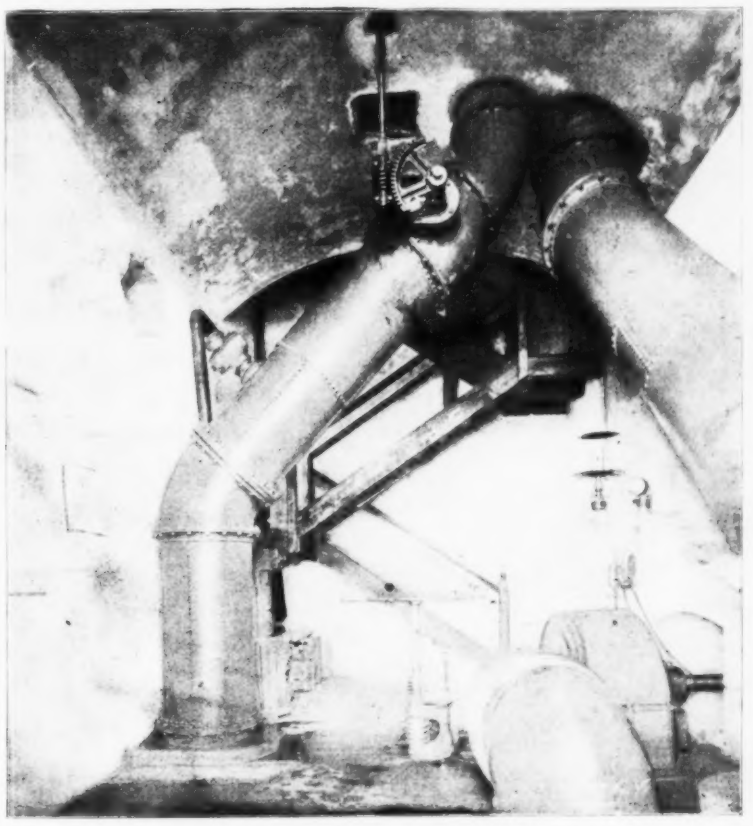
South Portal Before Its Completion.



Turbines and Pumps for Cooling Water in Northern Headings.

Water Power Intake for Ventilator House.

Observatory with Instruments Used in Determining the Line of the Tunnel.



Interior of Ventilator House.

THE COMPLETION OF THE SIMPLON TUNNEL.

THE COMPLETION OF THE SIMPLON TUNNEL.*

By CHARLES R. KING, C.E.

THE boring of the Simplon tunnel has at last been completed, the thin diaphragm of rock that separated the two headings having been finally burst through on February 24, 1905. The success of an enterprise of such magnitude marks this as the greatest event in civil engineering for several years past, during which time the work has been progressing quietly with persevering energy and patience, while the outside world has in the meantime changed with greater ease in its geographical and political bearings, suppressed nations and peoples, and sacrificed millions of lives at the altars of conquest and lawful depredations, as in the remotest ages of barbarism. But the boring of a simple tunnel could not, even with all the wealth of a dozen empires, and all their terrific armaments of blasting machinery, be accomplished faster even to please the rulers of peoples. However, the triumph here is quite different, and will endure hundreds of years, or time sufficient for empires and peoples to change national proprietorship several times over.

It is already known that the Simplon tunnel is 19.729 kilometers, or 12¼ miles, in length, constructed with twin passages, each 16½ feet wide, and separated by a distance of 55.7 feet between their axes; and that it is quite straight throughout save for a short curve at each of its ends, in order to join its tracks with the outside railroad lines, which have both to follow along narrow valleys or gorges (the Rhone valley in Switzerland and the Val Vedro in Italy), and with the alignments of which the tunnel forms an obtuse angle. The grade of the tunnel is, as is known, 2 per 1,000 from the Swiss portal and 7 per 1,000 from the Italian portal. The summit of the line, 704.3 meters (2,308 feet) altitude, is reached at 9.572 kilometers from Brig, and is situated in the subsoil of Italy. The greatest distance from the tunnel to the top of the mountain range is 7,005 feet, and the average distance is over 5,000 feet.

The new tunnel will bring not only Geneva and southwestern, or French, Switzerland into closer communication with Milan and the Adriatic railways of Italy, but it will shorten the distance from Calais to Milan 80 and 95 miles respectively over the other routes now passing through the Gotthard and Mont Cenis tunnels, which are 9½ and 7½ miles long.

The new Simplon route will eventually not only be a still shorter way to the Adriatic coast from north Switzerland (Basel), and from France (Paris), by means of other connecting lines yet to be constructed, but, most important of all, it will be an express route, practically level, which means fast trains and cheap freights as compared with the expensive operations of traffic over the Gotthard inclines. Had it not been for this, the tunnel might have been driven at a much higher altitude, and at an enormous saving in the cost of the work. The Swiss end of the tunnel has an altitude of 2,250 feet, and the Italian end 2,076 feet, while the tunnel summit is 2,310 feet.

The practice of boring mountains at as low a level as possible is likely to become general in the near future. Already plans have been made for piercing the Ligurian Apennines, north of Genoa (Italy) with a tunnel about 13 miles long, lying at a comparatively short distance below the surface, merely for the purpose of reducing existing surface gradients and thus facilitating traffic between this port and Milan, the industrial capital of Italy. The Wildstrübel in the Bernese Alps is, according to present plans, to be bored in order to connect the great international railroad center of Basel with the Simplon tunnel, and so effect a great saving of distance as compared with the detour now made by the present Simplon line *via* Lausanne and Lake Geneva.

HOW HOT SPRINGS ARE DEALT WITH.

In driving the Simplon tunnel, one of the great difficulties encountered was the influxes of hot water that occurred, first on the Swiss side, and later on the Italian side. The spring cut into at the southern end of the workings could never have been dealt with from the northern side.

This spring was the most formidable one encountered and yielded 80 liters (20 gallons) of water per second at a temperature of 46 deg. C. (114.8 deg. F.). It is located at the southernmost fringe of that great tract of subterranean water courses which had so much retarded, during the previous two years, the progress in the northern, or Swiss, workings, its exact position being at 9.14 kilometers from the southern portal at Iselle (Italy). This irruption occurred on September 6. Previous to this event, the boring in No. 1 main tunnel was calculated to be finished on October 16, 1904—had it been possible to maintain the previously-existing average of 6 meters per day. Instead, however, all work throughout the various constructional sections in the main tunnel had to be suspended. To combat this inflow, the first step was to enlarge the spring's orifice in the tunnel, in order to reduce the velocity of its inrush, and then cover up the opening with thick lagging boards to keep the water out of the heading, these boards serving besides as non-conductors of heat. The flow was subsequently led off through a special drainage transverse passage between the two tunnels, the work of boring which was rushed through, in order to enable the hot water to be promptly diverted into the main drain in the No. 2 secondary tunnel. This passage, about 125 feet to the rear of the hot spring, is the forty-fifth from Iselle (at 9.1 kilometers). The irruption of this hot-water spring increased the general air temperature in tunnel No. 1 to an average of 35 deg. C. (95 deg. F.) from an average temperature previously existing of only 27.8 deg. C. (82.04 deg. F.).

The ventilating air where delivered at the heading face previous to the inflow of this hot water was only 20.5 deg. C. (68.9 deg. F.), but afterward the temperature rose to 40 and 45 deg. C. (104 and 113 deg. F.) near the spring, though it was reduced to about 28 deg. C. (82.4 deg. F.) by means of batteries of cooling sprays, the water of which had a temperature of 16 deg. C. (60.8 deg. F.). This cooling water was pumped by a centrifugal pump run by hydraulic turbines, and by a 100 horse-power steam engine located in the tunnel, the pumps taking their supply from a large spring of cold water, which has been canalized in the tunnel about three miles farther back, where it occurs in cross passage No. 21A at 4.4 kilometers.

The spring mentioned has a temperature of 12 deg. C. (53.6 deg. F.), and a natural pressure at the rock outlet of 80 pounds per square inch. It is tapped by a 253-millimeter (9.96-inch) pipe surrounded with a jacketing of broken charcoal for keeping down its temperature; and this natural head of the water for a long time served all requirements for spraying the atmosphere.

Spraying heads located in each of the rearward transverse passages of tunnel No. 1 were used for cooling the air, and a special plant consisting of long perforated pipes, adjustable to all positions, was used, as at the Swiss end, for cooling the rock. In encounters with new hot springs in the northern or Swiss headings, the most efficacious method of preventing the hot water seriously raising the temperature of the air was to project a large volume of cold water right into the aperture from which the hot water issued, thus reducing the heat of the inflowing water from the very first. While this was going on, the aperture was excavated as rapidly as the conditions permitted, in order to reduce the velocity of the inrush, which was often such as to throw the water to a distance of sixty feet, and sometimes cause it to hurl pieces of rock that would occasionally wound a miner. After enlarging the orifice, planks were driven in vertically against the walls, and with other planks lapping their joints, the water was shut in and drained off into a deep channel or well, whence it was pumped to the top of the incline into the large channel drain of tunnel No. 2 of the north heading.

STATE OF THE TUNNEL HEADING AT THE SWISS SIDE.

At the Swiss, or north, end of the tunnel both headings were still full of hot water up to the time the headings were burst through. No. 1 main tunnel was filled for a length of 253 meters (835 feet), and No. 2 auxiliary tunnel for a length of 23½ meters (77½ feet), these distances being measured from the iron safety-gates which were finally erected across the tunnel in March, 1904, in view of the possible encounter with further hot water springs than those which had been met in the autumn of 1903.

EXPEDIENTS ADOPTED TO CONTINUE THE WORK AT SWISS SIDE.

The plant at Brig for the supply of power and refrigeration water was sufficient for requirements until the summit of the tunnel, at 9.572 kilometers from the north portal, and at 704.3 meters (2,310 feet) altitude, was reached, since the inclination of the tunnel of 2 per 1,000 was always adequate for the main drainage. Beyond that point, however, pumping became necessary in the parallel tunnel, No. 2, for its gradient then fell away from the Brig portal; but, with the hope of at last outpassing the region of hot springs without having to pump out the heading, No. 1 heading alone was continued onward on an up grade or false incline of 1½ per 1,000 until, at a distance of 400 meters (1,320 feet), the shaft struck the top of the tunnel (as shown in the cross-sectional diagram), so that a sudden descent of 25 per 1,000 in a length of 150 meters (495 feet) was then unavoidable in order to regain the level of tunnel No. 2.

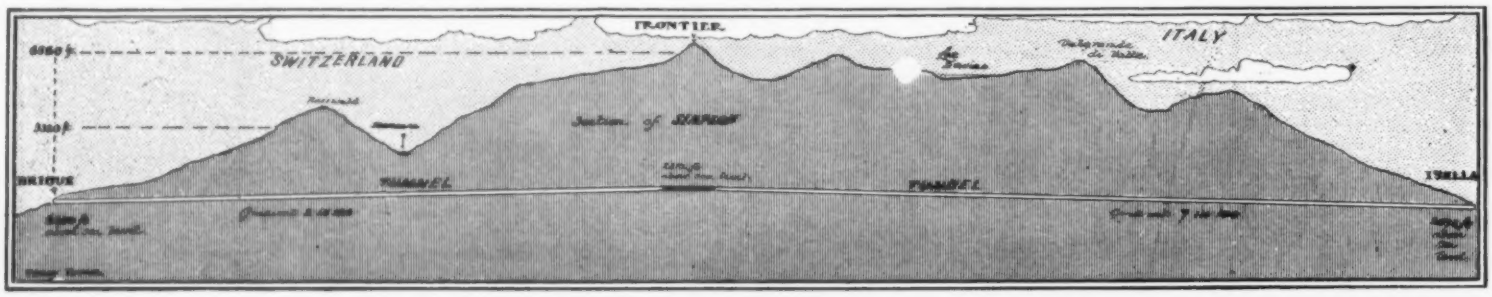
EXTRAORDINARY DRAINAGE PUMPING.

The difficulty of boring this portion was very great, as the rapid inclination made it necessary to employ a portable pipe line for the pumps in order to keep the heading face free of the water, which of course always flowed toward it. The pipe line and the pumps, of 13 gallons per second capacity, were mounted on trucks, which necessarily occupied the greater portion of the space in the advance heading. A windlass and chain were employed to lower the trucks with their pumping plant until the mines had all been charged and made ready for detonation. Then the pumps, having drained the heading face quite dry, were pulled back out of danger together with the other tools, rock borer, etc., until the whole blast had been fired.

FIRING MINES IN FLOODED HEADINGS.

Especial precautions were taken to avoid misfires and subsequent accidents, for, as is known, damp is detrimental to dynamite. Tail ends of holes were always probed where these remained after a blast. Auxiliary holes were sometimes bored in the lower row, next the floor, in order to be more certain that the whole of the charge there had been exploded.

After the lift had been effected and the spoil removed, up the incline, the pumps had to be got to work again without delay. All this had to be carried out in a steaming atmosphere, frequently charged with the fumes of explosives, and with barely space to move past the various pipes and mains for the pumps, for the refrigeration water, for the free and compressed air, and also for the hydraulic power, all of which encumbered the flooded tunnel.



Sectional View Showing How the 12¼-Mile Tunnel Pierces the Simplon Range.

On the Swiss side of the mountain range (shown to the left of the view) the tunnel enters the mountain range at Brig at a height of 2,250 feet above sea level. The dotted lines which appear on the section show the height of the mountain above the tunnel. The tunnel rises slightly until it reaches a small level portion under the highest part of the Simplon range and then falls again gradually at a slightly steeper gradient to Iselle, at which point the traveler will find himself well within the Italian frontier. In his journey through the tunnel he will have passed under Lac d'Avina. The gradients of the tunnels were specially planned in this way to carry off the water which the engineers expected to encounter, and which they did encounter to a much greater extent than they desired and at such a suffocating temperature as to temporarily put a stop to the work.

DESPERATE WORKING.

Added to these regular conditions of the work were the occasional accidents of burst or injured pipes, against which contingencies every provision had to be made, with spare parts ready to hand for emergency; while the bursting in of some fresh source of hot water had to be anticipated, and due arrangements made for dealing with it before the atmosphere of the tunnel could be greatly raised in temperature. Under such conditions of the atmosphere the miners were exhausted in a short space of time, and the shifts had be frequent, and the men in each gang specially selected for their endurance.

MOMENTARY RELIEF FOR THE FLOOD WATER.

When the heading of No. 1 had at last reached down the incline to the level of tunnel No. 2, at the bottom of the grade, a transverse passage was run through into the latter with a grade of 1.67 per cent, and through this all the water was drained into No. 2 from the 25 per 1,000 grade described, and also from the new heading of No. 1, which was once more advanced in counter grade, but with an inclination this time of only 1 per 1,000 (see diagram showing side elevation). At the foot of the grade named, and in both tunnels to the north of the transverse passage, the safety gates were erected in the middle of masonry passages 6 meters (19.68 feet) in length. In the cross passage No. 52, just beyond the gates, a fixed installation of more powerful pumps was made. The centrifugals are run by Pelton wheels, each one having a capacity of 9,600 liters (2,534 gallons) per minute.

AT THE IRON BARRIERS IN THE SWISS WORKINGS.

Beyond this point very little advance was made in tunnel No. 2, as it received all the water coming from the two headings; but No. 1, notwithstanding that the atmospheric heat had risen from 23 deg. C. to 31 deg. C. (73.4 deg. to 87.8 deg. F.), was still driven on 199 meters (656.7 feet) during the last three months of the work and with an average sectional area of 6.1 square meters (65½ square feet). The progress of boring the main tunnel in the month of May was exceptionally

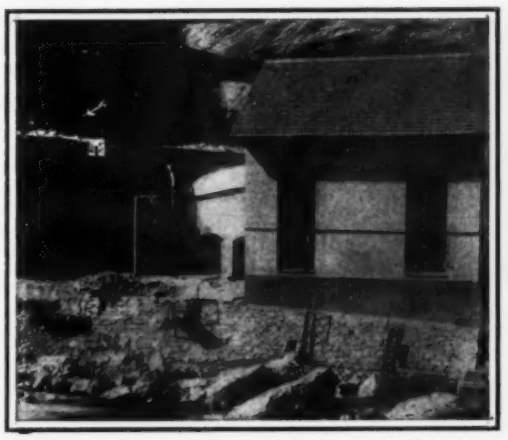
* Specially prepared for the SCIENTIFIC AMERICAN SUPPLEMENT.

good, varying from 2.2 meters (7.21 feet) to as much as 5 meters (16.4 feet) per day, and averaging altogether 3¼ meters (10.66 feet) daily. In the last 200 meters (660 feet) the rocks traversed were exclusively of silicious and micaceous crystalline limestone, of gray and gray-white color, with seams tending uniformly north to west from 15 deg. to 20 deg., the stratifications occurring in regular layers up to the last 90 meters, whence they were tumbled and broken and accompanied by secretions of calcite. Across the strata west to east were fissures which coincided with the great infiltrations of hot water. Another of these was cut into at advance point 10.376 kilometers. It yielded 35 liters (9¼ gallons) of water per second at a temperature of 44 deg. C. (111.2 deg. F.). At this time (May 18) the hydraulic power for the pumps was found insufficient to deal any longer with all the infiltrations, including also the large quantity of cold water forced into the heading for indispensable cooling purposes, and the order was then given to shut the flood gates. In order to reduce the pressure, discharge pipes were placed in these doors, through which there was a considerable flow of water. At the north portal this amounted to 146 liters (51¾ gallons) per second.

RETREAT BEFORE THE OVERWHELMING WATER, SWISS SIDE.

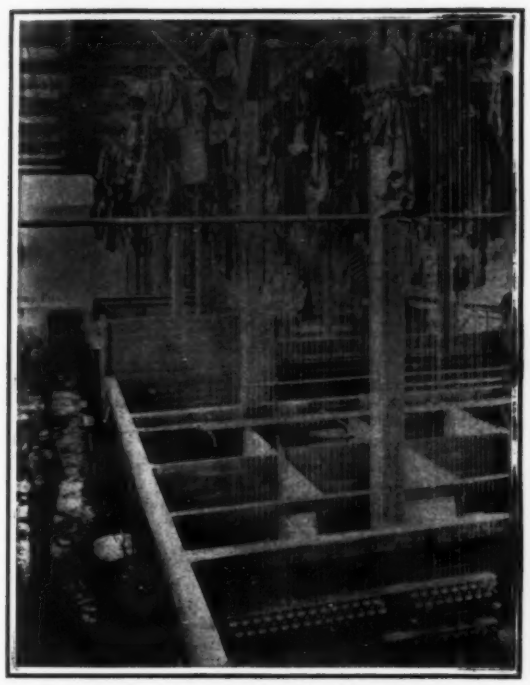
Notwithstanding the difficulties of the work, an at-

South Portal of the Simplon Tunnel Partially Completed.



Ventilating House and Its Connecting Passage Leading into the Tunnel.

Ventilating Fan House at Iselle. Changing Duty from One Fan to Another.



Drying House for Miners' Wet Clothes.

Where the Tunnel Enters the Range on the Italian Side.

The view is taken close under the mountain range, showing the entrance to the tunnel near Iselle. The hospital, hotel, and offices necessitated by the works are also shown, together with Iselle Railway Station to the right.

Where the Tunnel Enters the Simplon Range on the Swiss Side.

The tunnel enters the mountain in the Rhone Valley near Brig. Some of the numerous offices, workshops, hospitals and dwelling-houses necessitated by the tunnel works are shown in the foreground. It will be noticed that the tunnel has to pierce a lower shelf before it passes under the greater heights of the range.

Battery of Sprays Cooling Walls of the Headings.

THE COMPLETION OF THE SIMPLON TUNNEL.

tempt was made to haul out all the rock-borers and the pumping plant in the two headings and in the large transverse passage No. 52. While occupied in these operations, the pumps in this passage ceased to work through the main water power having been interrupted by a landslide which occurred at Mörel, a point a little above the intake of head-water from the river Rhone, and which supplies the whole hydraulic force at the Brig power station. A hurried exodus of the men on the shift then took place, and the safety-gates were closed immediately, to prevent the whole tunnel from becoming a watercourse carrying with it insufferable heat. The gates remained closed until the headings of the north and south tunnels were pierced and the water drawn off through the latter.

(To be continued.)

SOME COMMON DEFECTS IN TIMBER AND THEIR CAUSES.*

By HAROLD BUSBRIDGE.

MANY features of wood which are regarded as defects by the timber merchant are the necessary result of the life of the tree, and hence timber could not be grown without them. Such defects may therefore be termed "essential," or unavoidable; although these can never be entirely eliminated, it is nevertheless possible by proper treatment during growth to reduce some of them to a minimum. By careful selection of the wood from the best parts of the log after felling, we may

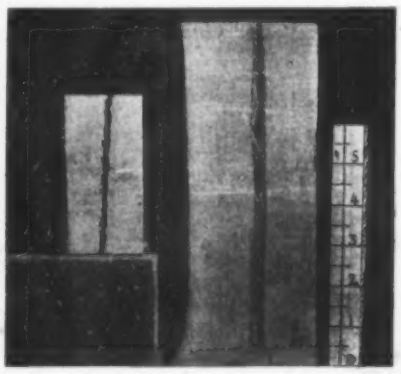


FIG. 1.—LONGITUDINAL SECTIONS OF ELDER AND HORSE-CHESTNUT, SHOWING MEDULLA.

further avoid some defects, while others may be entirely removed.

Let us, then, consider first those essential parts of a tree which are generally looked upon as blemishes by those who make use of timber for structural and other purposes.

1. The medulla, or pith, forms the axis of every tree trunk and of every branch. It is formed at the very earliest stage of growth, and when very soft, as is sometimes the case—in horse-chestnut and in elder, for instance (Fig. 1)—it renders the center of the log unsound, so that balks, deals, or battens which contain the center are defective.

Pitch pine and inferior yellow deal are often found to have soft and defective pith, thus reducing their market value to a considerable extent; but, as a rule, most timbers can easily be obtained with perfectly sound centers.

2. Most architects' and engineers' specifications require that timber shall be free from sap. Now in every tree the last few, and therefore outermost, annual rings formed consist entirely of sapwood, and it is by means of these outer rings that the branches, leaves, and fruit are supplied with nourishment from the soil upon which the tree grows. The only way, therefore, to obtain wood free from sap is to cut away all the outer rings which form the sapwood. It is well known that in nearly all timbers the sapwood, or "alburnum," is softer, contains more moisture, shrinks more, is less durable, and is more liable to the attacks of parasitic

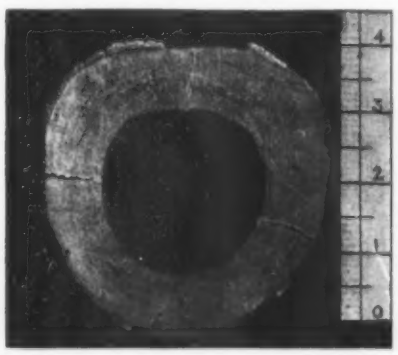


FIG. 2.—TO ILLUSTRATE DISTINCTION BETWEEN "SAPWOOD" AND "HEARTWOOD."

plants and insects than the "duramen" or heartwood. Fortunately, sapwood can generally be easily recognized by its lighter color (see Fig. 2); while in the case of yellow deal and other coniferous timber, it is often stained of a blue or greenish color by the water in which it is floated down to the port of shipment. Large and well-matured trees always have a smaller proportion of sap than young trees; hence it is always best to select for felling only those trees which have

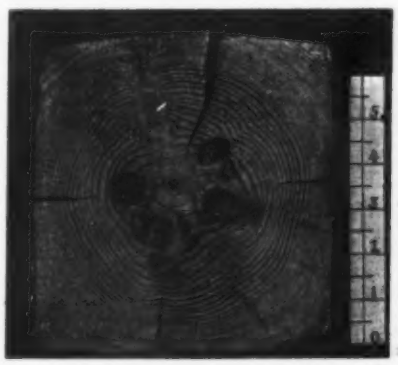


FIG. 3.—KNOTS IN YELLOW DEAL.

reached maturity. In dark-colored woods the sapwood is often very light in color. Thus the sapwood of ebony is nearly white; and of cocus-wood, of which the heartwood is very dark brown, the sapwood is pale yellow (Fig. 2).

3. Knots are always regarded as troublesome, especially by those who have to work the material; and when the grain of the wood is exposed to view in the finished work, they are considered to be serious defects if either large or numerous.

When it is remembered that they really mark the origins of branches, it will at once be understood that to have wood free from knots, it will be necessary to grow trees with stems free from branches. This, of course, is much easier to do in some kinds of wood than in others. When trees are grown close together in plantations, they tend to run straight up to a considerable height before throwing out branches, and hence their wood is more free from knots than that of similar trees grown in the open. In other cases, the stems may be kept free from large knots by lopping off, when quite young, all branches and shoots, until the head of the trunk is reached, where the principal branches separate.

Naturally the top ends of all logs are apt to have larger and more numerous knots than the butt ends. To get the best and straightest-grained timber, therefore, one always prefers the butt to the top end.

In most, if not all, coniferous timber, the knots run

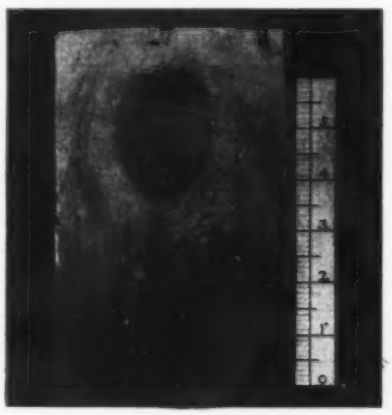


FIG. 4.—DEAD KNOT.

right to the center of the main stem; and in some cases, such as in yellow deal (*Pinus sylvestris*), the knots occur in regular groups of about five, at intervals throughout the length of the stem. These groups are termed "nodes," and often give a ready means of distinguishing the timber from other kinds, by the regular groups of knots which appear on the face of a board or plank cut from such a tree. Fig. 3 gives a cross section with a typical group of knots as they occur in yellow deal.

In dealing with boards and planks cut from coniferous trees, one often meets with what are known as "dead" or "loose" knots. Such knots are not firmly united to the adjoining wood, but are often surrounded by a ring of dead bark, and can easily be separated—in fact, they often drop out of their own accord. They are caused by the branch they represent dying, or having been broken off, while the parent stem was still growing. Part of the old branch thus becomes embedded in the new wood, and having no vitality, the knot shrinks, and thus becomes loose. Fig. 4 represents a dead knot occurring in a piece of American yellow pine.

A second group of defects met with in timber includes those which are not essential parts of a healthy tree, but are formed by mishap or accident during its growth. They are always developed before the tree is felled, and may be regarded as either wholly or partially avoidable, if proper attention is paid to the growing tree.

Of this class, perhaps, the several kinds of "shake" should receive our first attention; not only because they are frequently met with in the ordinary timber of commerce, but because, more than almost any other defect, they ruin the material in which they occur.

Heartshake (Fig. 5), for instance, is met with in nearly every species of timber, although certain kinds, such as Indian teak and pitch pine, are more liable to it than most other woods. This defect is common to dicotyledonous trees as well as to the conifers, and it appears in trees grown in all kinds of soil and in many different climates.

When found, it seems to be an indication of incipient decay consequent upon old age. It generally consists of a single crack extending across the center of the tree and diminishing in width toward the circumference.

Sometimes two such cracks cross each other nearly at right angles, but in all cases the defect may be distinguished from side shake by the cleft being widest at the pith or center. If the grain of the tree is pretty straight, and the clefts not very extensive, this defect does not injure the timber seriously, since by causing the saw cuts to follow the direction of the shake, fairly sound boards or scantling may be obtained. The worst form of the defect happens when the grain of the tree is twisted, as in Fig. 12, so that, perhaps, a single cleft may twist through 90 deg. in the length of the log. In such a case it is practically impossible to obtain from the tree a single wide board entirely free from shake.

If, instead of one or two, we find several shakes

FIG. 5.—HEARTSHAKE.

radiating from the center, as in Fig. 6, we have what is termed a "starshake."

This may be regarded as an aggravated and more extended form of the fault last described, and is found in trees of all ages and conditions of growth. In extreme cases, the clefts reach almost or quite to the circumference of the log, and sometimes they are so numerous and so extensive as to render the log quite unfit for conversion into smaller scantling or into boards. Heartshake and starshake generally indicate that decay has set in, owing to air and moisture having gained access to the center of the tree. This may happen after the loss either of a branch or a root, if the wound is not properly protected.

When once oxygen gains access to wood in a moist condition, oxidation of the wood substance sets in, and the inevitable shrinkage which follows chemical decomposition sufficiently accounts for the appearance of the clefts.

Closely related to the defects last considered are the decayed hearts (Fig. 7), of which numerous examples must be familiar to all those having any acquaintance with our parks and woods.

Sometimes logs are found in which heartshake and starshake are accompanied by partial decay starting from the pith; and since it is almost impossible to arrest decay when once begun, the originally sound tree is certain to develop into a hollow one.

The sap necessary to the life of the tree flows ex-

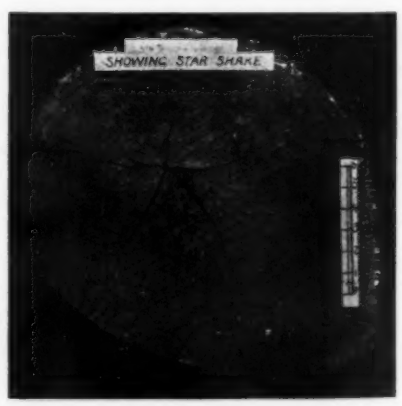


FIG. 6.—STARSHAKE (ASH, *Fraxinus excelsior*).

clusively through the alburnum or sapwood, and hence the whole of the heartwood may decay without seriously impairing the vitality of the tree. When decay has advanced so far that most of the heartwood is affected, the tree may be regarded as practically worthless for

* Technics.

constructive purposes, except perhaps in the case of common elm, of which the sapwood is said to be as durable as its heartwood.

The defect known as cupshake, ringshake, or shellshake (Fig. 8) is of a different nature, and is frequently met with in many kinds of wood. It consists in a partial or entire separation of two consecutive annual rings, and appears on a cross section as one or more splits running concentrically around the log.

Sometimes such shakes jump radially across several rings and continue their course in a wider circle. This defect occurs in perfectly sound and healthy looking trees, and is frequently met with in yellow deal from Archangel and elsewhere; also in Virginian pitch pine, and in lignum vitæ from San Domingo.

Opinions differ as to its cause, some attributing it to forest fires scorching the base of the tree, and so preventing the perfect cohesion of the next-formed annual ring; while others consider that severe frosts have a similar effect. Possibly, too, the effect of high winds upon tall soft-wood trees, in bending them, may cause the shearing stresses induced between the annual rings to produce ruptures which appear in the timber as already described.

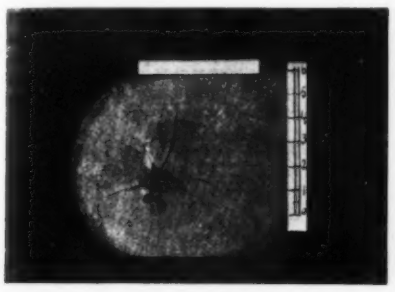


FIG. 7.—DECAYED HEART (ASH, *Fraxinus excelsior*).

An "upset," or, as it may be termed, a "transverse shake" (Fig. 9) is much more rarely met with, and, so far as I know, is found exclusively in foreign hardwoods, grown chiefly in tropical or sub-tropical climates. It consists of a complete severance of the longitudinal fibers of the tree in certain spots; but, as a rule, the defect is not very extensive. Mahogany and teak are often affected by it, and boards containing such upsets will break off suddenly without warning. I have heard workmen attribute this defect to the effects of lightning; but this, to me, seems very improbable. A much more reasonable explanation is that such trees, during their lifetime, have been exposed to severe hurricanes, which, although of insufficient power to uproot the tree, have nevertheless succeeded in permanently injuring the trunk by partially severing the fibers, either by tension on the windward side, or crushing by compression on the leeward side.

After the gale, the tree has had sufficient vitality to continue its growth, and so enfold its crippled stem in a new sheath of sound wood.

Fig. 10 represents decayed or "druxy" knots. Sometimes such knots are met with embedded in fairly sound wood, but in most cases, the effects of the decay run far down into the parent stem, while sometimes

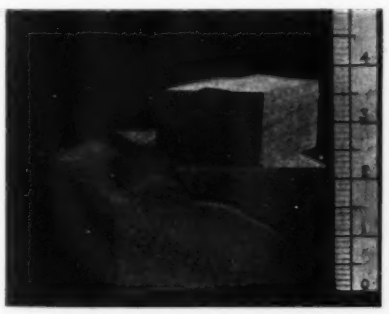


FIG. 8.—CUP, RING, OR SHELLSHAKES.

a tree may be quite ruined by one. In fact, heartshake, starshake, and decayed heart often owe their origin to a decayed knot.

When a branch is severed from the parent stem the wound is gradually covered by successive annual rings of wood from the trunk, each overlapping the last formed ring, until the wound is healed. Several years must, therefore, elapse before the wound left by the removal of even a small branch can be covered over by new wood, more time being required in proportion to the size of the wound. During this time decay may set in over the exposed surface, by the action of moist air alone; but it is more often hastened by the attacks of parasitic insects, by fungi, and by bacteria.

When this happens, the knot, instead of remaining sound, becomes "druxy," and often the wood around it is completely spoiled.

A "rind gall" (Fig. 11) owes its origin to the partial removal of bark from the trunk of a growing tree. This may be due to willful mischief on the part of boys or others, or to the action of certain animals in rubbing their horns or gnawing off the bark with their teeth.

Since deposits of new wood can be formed only beneath the protective bark, all growth ceases over those areas which have been denuded of bark. Nature, however, immediately sets to work to repair the damage. The next formed annual ring overlaps the edge of the

FIG. 9.—TRANSVERSE SHAKE.

wound on all sides, so as to reduce its area. The succeeding ring overlaps the last still further, and so on, until after a certain number of years the bared trunk is completely covered with new wood, all inclosed within a protective envelope of bark. Of course the success of Nature's effort, from the practical man's point of view, depends on whether or not decay has set in before the wound has been covered with new wood. In the former case, the wood remains sound, and no injury results to the timber, while in the latter case the damage may be serious.

Many trees have their vertical elements arranged in a slightly spiral direction, instead of growing parallel to the axis of the trunk. The cause of this peculiarity does not seem to be fully known, although several theories have been advanced to account for it. It has been thought that when a tree is not equally exposed to sunlight on all sides, it may rotate upon its axis in an effort to give its sheltered sides more sun, thus producing a twisted grain. Another theory is that the prevailing winds, acting upon any exceptionally large branch, exercise a turning effect upon the trunk, the

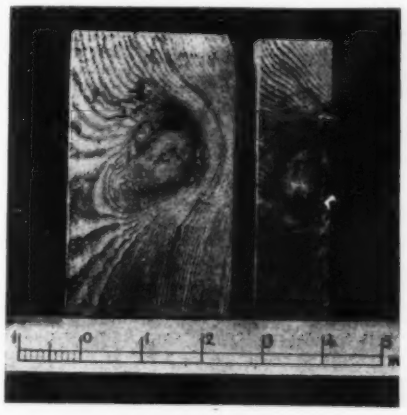


FIG. 10.—"DRUXY" KNOTS.

result being the twisted grain already remarked. Boards and planks cut from such trees prove unusually troublesome to the builder, since they not only contain a great deal of "cross grain," but in seasoning the grain is very apt to untwist, thus giving rise to excessive waste in the operation of truing up. Not only so, but any shakes which may occur, as in the pole shown in Fig. 12, follow the direction of the grain, and often ruin the whole log. The warped doors and framing so frequently noticed in buildings may generally be traced to timber affected with this defect. The drawing board shown on the left-hand side of Fig. 12 affords a case in point.

Some trees have grown from saplings of which the stems were originally very crooked. They tend to straighten themselves with advancing age by adding more wood on the concave sides of the bends, so that

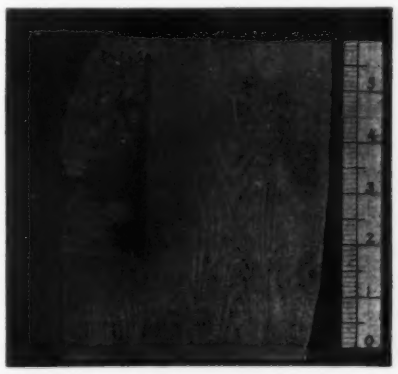


FIG. 11.—RIND GALL.

ultimately a fairly straight trunk may be produced. Boards and planks cut from such trees sometimes exhibit the defect known as "wandering heart." They contain a large amount of cross-grain, besides which, in seasoning, they warp very unequally, and sometimes curve in opposite directions in different parts of their length. The reason for this will be apparent when it is remembered that a plank cut from the center of the log may have the pith considerably below its surface in some places, while in others it would be considerably above it. This defect is most often met with, and is most troublesome, in English oak, elm, and other hardwoods which have an irregular habit of growth.

One other defect known as "inbark" (Fig. 13) may be referred to. It is caused by the inclusion of portions of the external bark within sound wood.

It often occurs where branches separate from the trunk, and is caused by their growing together in the hollow of the fork. Some trees are more liable to this defect than others, and it proves especially troublesome in some of the fancy hardwoods, such as burr walnut, employed by the cabinet-maker, in which a small piece of dead bark may spoil an otherwise valuable log. Generally speaking, in timbers used constructively it is seldom found to any serious extent.

FIG. 12.—WEATHER SHAKES AND TWISTED GRAIN.

The defects which originate after timber has been felled must be dealt with in another article.

SPONTANEOUS IGNITION OF BITUMINOUS BRIQUETTES.

IN recent years many fires have been caused by spontaneous ignition of briquettes made of soft coal (*Braunkohle*).

Prof. Medem, of Griefswald, in his book* on spontaneous combustion states that 149 cases of spontaneous ignition of briquettes occurred in the years 1902 and 1903 within the police limits of Berlin alone. In 87 of these cases the fires started on the railway while the briquettes were in transit from the factory to the city.

The heat of summer seems to increase the danger, for 73 cases of spontaneous ignition occurred in June, July, August, and September. In most of the 62 cases in which the ignition took place in the cellars and

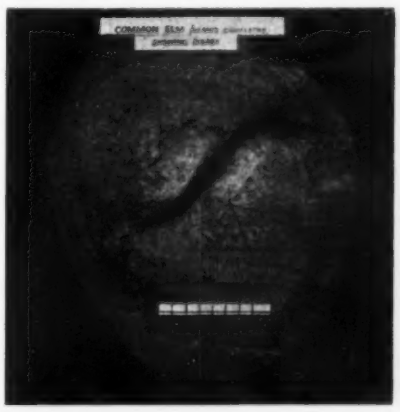


FIG. 13.—"INBARK."

yards of unsuspecting purchasers, it occurred in from one to three weeks after arrival. In one case three months elapsed between arrival and ignition.

In the manufacture of briquettes the coal is broken, pulverized, heated, and pressed into brick form. The exact chemical and physical changes which lead to spontaneous ignition are unknown, but it appears certain that the danger disappears after long keeping.

Prof. Medem recommends, therefore, that manufacturers be required to stamp each briquette with the date of its manufacture under penalty of liability for damages caused by spontaneous ignition of briquettes not thus stamped. Such a regulation would at least diminish the frequency of spontaneous ignition until its cause has been investigated and the making of perfectly safe briquettes rendered possible.

* Ueber Selbstentzuendungen und Brandstiftung. Griefswald, Julius Abel.

[Concluded from SUPPLEMENT No. 1524, page 24427.]

THE ELEMENTS: VERIFIED AND UNIFIED.[1]

IT has been shown by the researches of Newton, Dale, Gladstone, Jamin, Schrauff, Landolt and others that the refractive power increases in all liquids, except in water, between 0 deg. and 4 deg. with the increase of density—that is, with decrease of temperature. Rydberg showed that various solid bodies, such as quartz and aragonite, follow the same law. There are some exceptions, however. Among these is glass, as proved by Arago and Neumann prior to Rydberg. "On a rise of temperature all phenomena of absorption or emission are displaced toward the violet with the glass prisms, but toward the red with quartz prisms. These displacements are the greater the more refrangible the region of the spectrum in which they occur." As the result of a large number of observations, Krüss learned that by a variation of 25 deg. marked changes would be observed in the spectroscopic lines. From a table given, it could be seen that errors may spring from neglect of the temperature (of the instrument?) in stating wave-lengths, since a rise of 5 deg. is sufficient to transfer the D_1 to the position D_2. Roscoe obtained an entirely new spectrum with the metal sodium, whereby it appears that this metal exists in a gaseous state in four different degrees of aggregation, as a simple molecule, and as three or four or eight molecules together.

Grünwald in a series of papers on his theory of spectrum analysis[37] endeavors "to discover relations between the spectra and thus to arrive at simpler, if not fundamental 'elements.'" He came to the conclusion that "all the so-called elements are compounds of the primary elements *a* and *b*" (coronium and helium). Ames,[38] having called attention to the use of uncorrected data by Grünwald, remarks: "The concave grating gives the only accurate method of determining the ultra-violet wave-lengths of the elements; and as a consequence of not using it, most of the tables of wave-lengths so far published are not of much value."

Hutchins and Holden,[39] after a comparative study of the arc spectra of metals and the sun with a 21-foot focal Rowland grating, state: "We are convinced that there is much in the whole matter of coincidences of metallic and solar lines that needs re-examination; that something more than the mere coincidence of two or three lines out of many is necessary to establish even the probability of the presence of a metal in the sun. With the best instruments the violet portion of the solar spectrum is found to be so thickly set with fine lines that, if a metallic line were projected upon it at random, in many places the chances for a coincidence would be even, and coincidences could not fail to occur in case of such metals as cerium and vanadium, which give hundreds of lines in the arc."

"Moreover, a high dispersion shows that very few lines of metals are simple and short, but, on the contrary, winged and nebulous, and complicated by a great variety of reversal phenomena. A 'line' is sometimes half an inch wide on the photographic plate, or it may be split into ten by reversals."

Lockyer maintained that the lines of certain brilliant substances vary not only in length and in number, but also in brilliancy and in breadth, depending upon the quantity of the substance as well as temperature.[40] Being unable to decompose the elements in the laboratory, he studied the spectra of the stars. The spectra of the colder stars[41] show many more metals, but no metalloids, whereas the coldest stars, A Orionis, show the Crookes spectrum of metalloids which are compounds. None of the metalloids are found in the spectrum of the sun. Over 100,000 visual observations and 2,000 photographs were made in the researches.

Liveing,[42] as the result of the work of Young, Dewar, Fievez, and himself on the spectrum of the sun, by which some lines were resolved with a new instrument, which they before had not been able to devise, comments on Lockyer's work: That the coincidence of rays emitted by different chemical elements, especially when developed in the spark of a powerful induction coil, and the high temperature of the sun and stars, gives evidence of a common element in the composition of the metals which produce the coincident rays. "This result can not fail to shake our belief, if we had any, in the existence of any common constituent in the chemical elements, but it does not touch the evidence which the spectroscope affords us that many of our elements, in the state in which we know them, may have a very complex molecular structure."

Hartley[43] in his recent admirable address said:

"I have always experienced great difficulty in accepting the view that because the spectrum of an element contained a line or lines in it which were coincident with a line or lines in another element, it was evidence of the dissociation of the elements into simpler forms of matter. In my opinion, evidence of the compound nature of the elements has never been obtained from the coincidence of a line or lines exclusively belonging to the spectrum of one element with a line or lines in the spectrum exclusively belonging to another element. This view is based upon the following grounds: (1) Because the coincidences have generally been shown to be only apparent, and have never been proved to be real; (2) because the great difficulty of obtaining one kind of matter entirely free from every other kind of matter is so great that where coincident lines occur in the spectra of what have been believed to be elementary substances, they have been shown from time to time to be caused by traces of foreign matter, such as by chemists are commonly termed impurities; (3) no instance has ever been recorded of any homologous group of lines belonging to one element occurring in the spectrum of another, except and alone where the one has been shown to constitute an impurity in the other; as, for instance, where the triplet of zinc is found in cadmium and the triplet of cadmium in zinc the three strongest lines in the quintuple group of magnesium is graphite, and so on. The latest elucidation of the cause of coincidences of this kind arises out of a tabulated record from the wave-length measurements of about three thousand lines in the spectra of sixteen elements made by Adeney and myself. The instances where lines appeared to coincide were extremely rare; but there was one remarkable case of a group of lines in the spectrum of copper which appeared to be common to tellurium; also lines in indium, tin, antimony, and bismuth which seemed to have an origin in common with those of tellurium."

The last sentence presents the point I wish to emphasize. Tellurium has long obtruded itself before a satisfactory vision of the natural system. The table alone recites not a few efforts to obtain the contaminating constituent of tellurium which *a priori* is present from Hartley's observations (see also Grünwald 1889 table). The fractionation of a rubidium-cæsium mixture, perhaps, is a simpler problem than that confronting Pellini,[44] who reports a definite amount of an element with a high atomic weight (about 214), similar to and associated with tellurium.

What has been said applies especially to the elements of the rare earth class—"asteroids of the terrestrial family"—as phrased by Crookes. Many of them have not been secured with sufficient purity to claim an inherent spectrum; further, the spectra attributed have not been obtained under uniform conditions.

I have referred[45] somewhat in detail elsewhere to the factors producing variations in the absorption, as well as the advantages and disadvantages of the phosphorescent and reversal spectra.

Without doubt the spectroscopic criteria are the most valuable we have in judging finally the elements, and mayhap will remain so, but in my humble opinion, such have not alone sufficient authority, as yet, to usher the aspirant to a place among the elect. The contention frames itself, however, in an expression of the need for uniformity.

Whether we follow the most advanced metaphysico-chemical teachings or no, if there be any one concept upon which modern practical chemical thought depends, it is the law of definiteness of composition. There may be, and doubtless are, definite, perhaps invariable, properties of our elements other than their combining proportions, the atomic weights, if you please, yet, as far as we know, they approximate more closely than any fixed, if not permanent, ratios. Many of these values, by which we lay such store, are dependent upon data[46] in which, I venture the assertion, too great confidence has been bestowed, or opinions to which sufficient attention has not been given.

Although in this connection we shall give little heed to the suggested variability of the relative values, it may be remarked that Boutlerow, noting the variations observed in 1880 by Schützenberger, who, by the use of different atomic weights, obtained analyses summing 101 instead of 100, expressed the opinion that the chemical value of a constant weight, or rather mass of an element, may vary; that the so-called atomic weight of an element may be simply the carrier of a certain amount of chemical energy which is variable within narrow limits. (See also Crookes.) Wurtz's summary of Boutlerow's views, at a meeting of the Chemical Society of Paris, provoked an interesting discussion. Cooke later published a statement that he had expressed similar views more than twenty-five years before. That is, in 1855, he had questioned the absolute character of the law of definite proportions and had suggested that the variability was occasioned by the very weak affinity between elements manifesting a fluctuating composition. Without doubt "The Possible Significance of Changing Atomic Volume,"[47] in which a suggestion as to the probable source of the heat of chemical combination is put forward by T. W. Richards, bears directly on this phase of the problem.

While the atomic mass values depend directly upon the ratio between the constituents of the compounds, they rest equally upon the molecular weights. Many of the latter attributed to salts of some of the rare earths depend solely upon the specific[48] heat determinations of Hillebrand and Norton,[49] Nilson and Pettersson,[50] who, in the light of subsequent investigations, we know, worked with complexes. To be sure, those elements which were apparently exceptions to the law of Dulong and Petit possess low atomic weights (beryllium, boron, carbon, silicon, aluminium, and sulphur) and have for the most part been brought into harmony. "The specific heats of all substances vary with the temperature at which they are measured; and though the variation is often slight, it is occasionally of relatively great dimensions. When this is so in the case of an element, the question arises: At what temperature must the measurement of the specific heat be made in order to get numbers comparable with those of the other elements? No definite answer has been given to this question, but it is found that as the temperature rises, the specific heat seems to approach a limiting value, and this value is not in general far removed from that which would make the atomic heat approximately equal 6.4"[51] In view of this, allotropism, and the work of Richards adverted to, it appears that a revision of the specific heat values now taken is necessary before we can accept fully this law, which has been most helpful.

Time will not admit of detailed statements, and it is unnecessary in this presence to more than call attention to the fact that what has been said is not applicable to each specific case. "*La critique est facile, mais l'art est difficile*," as Berthelot[52] has said, yet we must appreciate that all our laws have their limitations. "Man being servant and interpreter of nature, can do and understand so much, and so much only, as he has observed in fact or in thought in the course of nature. Beyond this he neither knows anything nor can do anything."[53]

A glance at the extensive, even censored, list of claimants will evoke serious thought. "Thus was the building left ridiculous."[54] The difficulties briefly outlined and the causes for lack in uniformity are by no means insurmountable, but will continue until more systematic direction and prosecution of the work come about. Investigators in pure chemistry as a rule hold professorships, or other positions making equal demand upon their time. Furthermore, it is extremely rare that one man can become a master of the various delicate operations hinted at. Mallet[55] made a proposition for systematizing atomic weight work and F. W. Clarke in this country[56] and abroad[57] has urged the establishment of an institute for its prosecution. This appeals to all interested in what we are pleased to term the exact sciences, and doubtless in time will come about. For the time being, however, it is not unreasonable to suppose that a concerted appeal of the chemists of this country to the direction of the munificent endowment recently made American science for funds to clarify the elemental enigma presented above would not be in vain. There are splendidly equipped chemical departments in some of our great American universities which would make room for, and cordially welcome, I am sure, a selected corps of supported researchers, who would test the claims of each of these and other elemental aspirants. Such a community of effort should receive even greater substantial assistance from governments and corporations than has been accorded individuals. I need only refer to the aid given the Curies by the Austrian government, and generosity shown by the Welsbach Lighting Company in this country to several investigators, especially myself.

It must be evident to all that we are not indulging in special pleading, for every phase of that division of science designated chemistry rests upon what we choose to term the elements.

Victor Meyer,[58] referring to the fantasies of science, said: "He, however, who only knows chemistry as a tradition of perfectly clear facts, or who thinks to see the real soul of chemical study in measuring physical phenomena which accompany chemical transformations, feels no breath of this enjoyment." Reflecting upon the good and ill that have come to us through unrestrained imagination, we may give a careful acceptance of Newton's "Physics, beware of metaphysics" for as Clifford wrote, "Doubtless there shall by and by be laws as far transcending those we know as they do the simplest observations."

The graphic representation of the elements, "the foundation stones of the material universe which amid the wreck of composite matter remained unbroken and unworn," as Maxwell gracefully spoke of them, has often been mistaken for the periodic law. Carnelley's "reasonable explanations" of the periodic law were given a respectful hearing and forgotten.[59]

"Granting that the chemical characteristics of an element are connected with its atomic weight, we have, however, no right to assume them to be dependent upon that fact alone" (Liveing). Hinrichs says weight and form,[60] concerning the latter of which I am ignorant.

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[1] Address of the vice-president and chairman of Section C, Chemistry, of the American Association for the Advancement of Science, St. Louis meeting, December 28, 1903.

[37] Über das Wasserspectrum, das Hydrogen- und Oxygenspectrum," Phil. Mag., 24, 304, 1887. "Math. Spectralanalyse des Magnesiums und der Kohle," Monatshefte für Chemie, 8, 650. "Math. Spectralanalyse des Kadmiums," Monatshefte für Chemie, 9, 950.

[38] Am. Chem. J., 11, 138, 1889.

[39] "On the Existence of Certain Elements, Together with the Discovery of Platinum, in the Sun," Am. Jour. Sci.; Sci. Am. Supp., 25, 628, 1888.

[40] Roy. Soc. Proc., 61, 148, 183; Chem. News, 79, 145.

[41] Chem. News, 79, 147.

[42] Address before the Chemical Section of the British Association, Scientific American Supplement, 14, 356, 1882.

[43] Loc. cit.

[44] Gaz. Chim. Ital., 33, 11, 35.

[45] "The Rare Earth Crusade," loc. cit.

[46] Others have been referred to in the address to which this is a sequel. Loc. cit.

[47] Proc. Am. Acad. Arts and Sciences, 27, 1, 1901, and 27, 399, 1902.

[48] Berichte, 13, 1461, 1880.

[49] Pogg. Annal., 156 and following.

[50] Berichte, 13, 146, 1880.

[51] "Introduction to Physical Chemistry," James Walker, London, p. 33.

[52] "Les Origines de l'Alchimie," Paris, 1885.

[53] Bacon's "Novum Organum," Aphorism I.

[54] Milton, "Tower of Babel."

[55] Stas memorial lecture, Chemical Society (London), delivered December 13, 1892.

[56] Presidential address before the American Chemical Society.

[57] Wilde lecture at the Dalton Centenary, Manchester, 1903.

[58] Lecture on "The Chemical Problems of To-day" before the Association of German Naturalists and Physicians at Heidelberg, September, 1889; Chemical News, 61, 21.

[59] He regarded the elements as compounds of carbon and ether analogous to the hydrocarbon radicals, and suggested that all known bodies are made up of three primary elements—carbon, hydrogen and ether—truly an assumption which can not be disproved. Aberdeen meeting, British Association.

[60] "Atom Mechanics," Hinrichs, Vol. I., St. Louis, 1894, p. 242.

No doubt the pendulum lately has swung back toward Boscovician thought revivified by the like masters, Van't Hoff and Arrhenius.

Le Verier predicted the planet Neptune and his predictions were verified. While all of Mendelejeff's predictions, specific and tacit, have not been verified, some have. Ramsay[61] and others, without a periodic guide, predicted certain of the inert gases, which predictions have been verified.

Victor Meyer, in speaking of the completion of the Mendelejeff table, calls attention to the summing up of one hundred elements, from which it appears that 258 would be the limit to our atomic mass equivalents. I am not prepared positively to contradict such a conclusion at the present time, but there are reasons for thinking otherwise.

Clarke[62] has shown that the mean density of the earth, 5.5 to 5.6, is more than double that of the rocky crust, and "the difference may be accounted for as a result of pressure, or by supposing that, as the globe cooled, the heavier elements accumulated toward the center." While it is quite impossible to judge of the order of this intramundane pressure, I am not aware of such marked changes being brought about in the specific gravities of the heavier solid elements of their compounds, either by pressure, allotropic or isomeric changes, except the cerebral argentaurum of the late S. H. Emmens.[63] The examinations of volcanic dusts by Hartley,[64] Fleet,[65] and others appear to contradict the latter explanation, although we are unable to state the depth, perhaps within the shell considered by Clarke, at which volcanoes begin their boisterous activity. While awaiting a fulfillment of Martinez's[66] project to explore the earth's center, we may offer a third solution, not wholly unscientific, as it can do no harm, and has nought to do with any yellow peril in science, namely, the existence of elements with atomic weights higher than those set by the silent limit of periodic tables.

"Most molecules—probably all—are wrecked by intense heat, or, in other words, by intense vibratory motion, and many are wrecked by a very impure heat of the proper quality. Indeed, a weak force which bears a considerable relation to the construction of the molecule, can by timely savings and accumulation accomplish what a strong force out of relation fails to achieve."[67]

As hinted at in the earlier portion of this unduly prolonged address, many have theorized as to the ultimate composition of matter. The logic of Larmor's[68] theory, involving the idea of an ionic substratum of matter, the support of J. J. Thomson's[69] experiments, the confirmation of Zeeman's phenomenon, the emanations of Rutherford, Martin's[70] explanations, can not fail to cause credence in the correctness of Crookes's idea of a fourth state of matter.[71] In the inaugural address as president of the British Association (1898), he acknowledges in the mechanical construction of the Roentgen ray tubes a suggestion by Silvanus Thompson to use for the anticathode a metal of high atomic weight. Osmium and iridium were used, thorium tried, and in 1896 Crookes obtained better results with metallic uranium than platinum.

These and the facts that most of the elements with high atomic weights, in fact all above 200 (thallium not reported on),[72] exhibit radio-active properties, are doubtless closely associated and have to do with the eventual composition of matter. I have unverified observations which go to show the existence of at least one element with a very high atomic weight. If it be confirmed, then we have them now or they are making, and probably breaking up, as shown by that marvelous class of elements in the discovery of which the Curies have been pioneers.

If our ideas that all known elements come from some primordial material be true, then it stands to reason that we are coming in time, perhaps, to that fixed thing, a frozen ether, the fifth state of matter. I may make use of dangerous analogy and liken our known elements, arranged in a perfected natural system, to the visible material spectrum, while electrons, etc., constitute the ultra-violet and *cosmyle* composes the infra-red, either one of the latter by proper conditions being convertible into perceptible elemental matter. No positive evidence supports these ideas, but I like to fancy scientific endeavor as the sea—calm and serene, supporting and mirroring that which is below it, bearing that which is upon it, reaching to and reflecting that which is above it, moving all the while; yet, torn and rent at times by conflict from without and contest within, it runs; it beats against the shores of the unknown, making rapid progress here, meeting stubborn resistance there, compassing it, to destroy but to rebuild elsewhere; and the existence of those within it! "Like that of Paul, our life should be a consecrated unrest."

CHARLES BASKERVILLE.

[61] Address before the Chemical Section, British Association, Toronto meeting (1898).

[62] "The Relative Abundance of the Chemical Elements," F. W. Clarke, read before the Philosophical Society of Washington, October 26, 1899; Chem. News, 62, 31.

[63] Argentaurum papers published by Emmens. New York.

[64] Royal Society, February 21, 1901; Chem. News, 83, 174.

[65] Abstr. Proc. Geol. Soc., 1902, 117; Journ. Chem. Soc. (Lond.), 81-82, II., 518, 1902.

[66] "La Nature," Sc. Am. Sup., 21, 546, 1886.

[67] Tyndall in Longman's Magazine.

[68] Phil. Mag., December, 1897, 506.

[69] Phil. Mag., October, 1897, 312.

[70] Chem. News, 85, 205, 1902.

[71] Phil. Trans., II., 1881, 433.

[72] See the exquisite paper by Madame Curie on "Radioactive Substances," also "Radio-active Lead," Hofmann and Strauss, Berichte, 34, 3033, Pellini (loc. cit.) on "Radio-active Tellurium": Strutt, Phil. Mag., 6, 113, Elster and Geitel, Giesel, Marckwald, etc., etc.

RADIATION PRESSURE.*

A HUNDRED years ago, when the corpuscular theory held almost universal sway, it would have been easier to explain the pressure of light than it is to-day, when it is certain that light is a form of wave-motion. The means at the disposal of early experimenters were inadequate to detect so small a quantity; but if the eighteenth century philosophers had been able to carry out the experiments of Lebedeff and of Nichols and Hull, and had they further known of the emission of corpuscles revealed to us by the cathode stream and by radio-active bodies, there can be little doubt that Young and Fresnel would have had much greater difficulty in dethroning the corpuscular theory and setting up the wave theory in its place. The existence of pressure due to waves, though held by Euler, seems to have dropped out of sight until Maxwell, in 1872, predicted its existence as a consequence of his electromagnetic theory of light. The first suggestion that it is a general property of waves is probably due to Mr. S. T. Preston, who in 1876 pointed out the analogy of the energy-carrying power of a beam of light with the mechanical carriage by belting, and calculated the pressure exerted on the surface of the sun by the issuing radiation. It seems possible that in all cases of energy transfer, momentum, in the direction of transfer, is also passed on and that there is, therefore, a back pressure on the source. Though there is as yet no general and direct dynamical theorem accounting for radiation pressure, Prof. Larmor has given a simple indirect mode of proving the existence of the pressure which applies to all waves in which the average energy density for a given amplitude is inversely as the square of the wave-length. He has shown that when a train of waves is incident normally on a perfectly reflecting surface, the pressure on the surface is equal to $E(1 + 2u/U)$, where $E/2$ is the energy density just outside the reflector in the incident train, U is the wave-velocity, and u the velocity of the reflector, supposed small in comparison with U. In a similar manner it can be shown that there is a pressure on the source, increased when the source is moving forward, decreased when it is receding. It is essential, however, that we should be able to move the reflecting surface without disturbing the medium except by reflecting the waves.

Though Larmor's proof is quite convincing, it is interesting to realize the way in which the pressure is produced in the different types of wave-motion. In the case of electro-magnetic waves, Maxwell's original mode of treatment is the simplest. A train of waves is regarded as a system of electric and magnetic tubes transverse to the direction of propagation, each kind pressing out sideways, that is, in the direction of propagation. They press against the source from which they issue, against each other as they travel, and against any surface on which they fall. In sound-waves there is a node at the reflecting surface. If the variation of pressure from the undisturbed value were exactly proportional to the displacement of a parallel laver near the surface, and if the displacement were exactly harmonic, then the average pressure would be equal to the normal undisturbed value. But consider a layer of air quite close to the surface. If it moves up a distance, y, toward the surface, the pressure is increased. If it moves an equal distance, y, away from the surface, the pressure is decreased, but to a slightly smaller extent. The excess of pressure during the compression half is greater than its defect during the extension half, and the net result is an average excess of pressure on the reflecting surface. Lord Rayleigh, using Boyle's law, has shown that this average excess should be equal to the average density of the energy just outside the reflecting surface. In the case of transverse waves in an elastic solid, it can be shown that there is a small pressure perpendicular to the planes of shear, that is, in the direction of propagation, and that this small pressure is just equal to the energy density of the waves. The experimental verification of the pressure of elastic solid waves has not yet been accomplished, but the pressure due to sound-waves has been demonstrated by Altberg, working in Lebedeff's laboratory at Moscow, the pressure obtained sometimes rising to as much as 0.24 dyne per square centimeter. By means of a telephone manometer it was found that through a large range the pressure exerted on a surface was proportional to the intensity of the sound.

Both theory and experiment justify the conclusion that when a source is pouring out waves, it is pouring out with them forward momentum which is manifested in the back pressure against the source and in the forward pressure when the waves reach an opposing surface, and which, in the meanwhile, must be regarded as travelling with the train. It was shown that this idea of momentum in a wave-train enables us to see the nature of the action of a beam of light on a surface where it is reflected, absorbed, or refracted without any further appeal to the theory of the wave-motion of which we suppose the light to consist. In the case of total reflection there is a normal force upon the surface; in the case of total absorption there is a force normal to the surface and a tangential force parallel to the surface; while in the case of total refraction there is a normal force which may be regarded as a pull upon the surface or a pressure from within. In any real refraction there will be reflection as well, but with unpolarized light, in the case of glass, a calculation shows that the refraction-pull is always greater than the reflection-push, even at grazing incidence. An experiment, made by the president in conjunction with Dr. Barlow, was described to serve as an illustration of the idea of a beam of light being regarded as a stream of momentum. A rectangular block of glass was suspended by a quartz fiber so that the long axis of the block was horizontal. It was hung in an exhausted case with glass windows, and a horizontal beam of light was directed on to one end of the block so that it entered centrally and emerged centrally from the other end after two internal reflections. Thus a stream of momentum was shifted parallel to itself, or in this particular case a counter-clockwise couple acted on the beam. By suitable means the clockwise couple on the block, due to the pressures at the two internal reflections, was distinctly observed and approximately measured. The result obtained was of the same order as that deduced from the measurement of the energy of the beam by means of a blackened silver disk.

The extreme minuteness of these light forces appears to put them beyond consideration in terrestrial affairs, but in the solar system, where they have freer play, and vast times to work in, their effects may mount up into importance. On the larger bodies the force of the light of the sun is small compared with the gravitational attraction, but as the ratio of the radiation pressure to the gravitation pull varies inversely as the radius if the density is constant, the pressure will balance the pull on a spherical absorbing particle of the density of the earth if its diameter is about a hundred-thousandth of an inch. The possible effects of radiation-pressure may be illustrated without going to such fineness as this. In the case of a particle of the density of the earth, and a thousandth of an inch in diameter, going round the sun at the earth's distance, there are two effects due to the sun's radiation. In the first place, the radiation-push is 1/100 of the gravitation-pull, and the result is equivalent to a diminution in the sun's mass. In the second place, the radiation absorbed by the particle and given out again on all sides is crushed up in front as the particle moves forward and is opened out behind. There is thus a slightly greater pressure on the advancing hemisphere than on the receding one, and this appears as a small resisting force in the direction of motion. Through this the particle tends to move in a decreasing orbit, spiraling in toward the sun. As there is good reason to believe that some comets, at least, are composed of clouds of dust, there is hope that some of their eccentricities may be explained by the existence of radiation pressure. If the particles of a dust cloud circling round the sun are of different sizes or densities, the radiation accelerations on them will differ. The larger particles will be less affected than the smaller, will travel faster round a given orbit, and will draw more slowly in toward the sun. Thus a comet of particles of mixed sizes will gradually be degraded into a diffused trail lengthening and broadening, the finer dust on the inner and the coarser on the outer edge. If a planet, while still radiating much energy on its own account, captures and attaches to itself, as a satellite, a cometary cloud of dust in which there are several different grades, with gaps in the scale of size, it may be possible that in course of time the radiation-pressure effects will form the different grades into different rings surrounding the planet. Such may possibly be the origin of the rings of Saturn.

* Address delivered before the Physical Society by Prof. J. H. Poynting, F.R.S.

BACTERIOLOGY IN PUBLIC SCHOOLS.*

By WILFRED H. MANWARING, M.D., Department of Pathology and Bacteriology, University of Chicago.

THE history of early Europe impresses the student of hygiene, not so much with the poetry of certain centuries, as with the ravages of epidemics, the horror of disease and the disregard of sanitary laws that characterized the same periods. Few realize to-day that in the earlier centuries the average length of human life was less than twenty years, and infectious diseases so common that every third man was marked with smallpox.

Gradually there has been an improvement. Great epidemics have become unknown, disease and suffering have lessened, and human life has increased to an average of over 33 years.

This improvement has been due to many factors, such as better housing, better food, better habits. But the most prominent factor bringing about this change has been the rise and diffusion of correct ideas concerning the nature of disease.

The effect of such knowledge on the health of a community is nowhere more strikingly shown than in the results of recent educational campaigns against tuberculosis. In Massachusetts and New York city, where active measures have been taken to teach the consumptive the nature of his disease and to point out to him the ways in which he may become a menace to others, the death rate from tuberculosis has decreased, till it is to-day but slightly over half what it was twenty years ago. While in communities in which this educational warfare has not been carried out, the death rate from this disease has remained practically unchanged.

Seeing this result of popular knowledge, hygienists have dreamed of a future in which an adequate number of medical facts shall be known by all, in which disease and suffering shall be reduced two-thirds, and human life increased to the 50 or 60 years that is man's natural heritage. And dreaming thus, they have

* Reprinted from School Science and Math., January, 1905.

asked how this diffusion of knowledge can be brought about.

There are many ways in which medical facts can be put before the people. Lectures by medical men, house to house talks by sanitary workers, the distribution of literature. All are valuable. But they reach the people when it is too late for the full benefit of such knowledge, and they come equally emphatic with the wonders of somebody's cure-all, the marvels of another's special therapy, and all the clamor and nonsense devised by avarice and ignorance. To be efficacious, this knowledge must come early in life, and must reach the public through the mouth of authority.

There exists to-day such a means of reaching the people, a means thus far almost overlooked in the great world-fight against disease. This is the public high school. It deals with man midway between childhood and maturity, when interests are keen, impressions vivid, and the mind already trained to question and answer why. The primary and grammar schools come too early. The most that can be done in them is to state the simpler facts. The college comes too late. It is of use mainly as a means of training teachers for this work. A prominent educator has said that "the public high school is the most efficient means for the uplifting of the human race." In no way is this more true than in the fact that the high school is the best means for the diffusion of medical knowledge.

The high school being the point of attack, one asks what sort of instruction should be given here. A number of years of observation and experience with high school students convinces me that what is needed is something radically different from the text-book physiology and hygiene now given our boys and girls. There is needed a virulent subject, one that will lend itself to the strength of the student and leave in his mind facts that he himself has proved and for which he is willing to fight.

Such a subject is bacteriology. In the few high schools in which it has been tried, it has been found to be all that could be hoped for it.

The work in bacteriology that should be attempted in a high school, differs from that of the college or medical school. Just what will prove of most value here can be determined only by experience. There are numerous simple experiments, however, each bearing on a large question of preventive medicine, that could profitably form part of such work. Among them are such experiments as the demonstration of bacteria in air, water, and milk; as testing the effect of heat, cold, sunlight and antiseptics on germs; and as showing the bacteria-killing powers of gastric juice. Most of these experiments have already been tried with pupils of high school grade, and have been found to be of practical educational value.

To give such work requires little apparatus not now possessed in the average high school. It does require, however, a special training now possessed by but few secondary teachers. The opportunities to acquire this training, however, are so good, and the training itself requires such a small outlay of time and effort, that no school board is justified in not demanding it of its teacher of hygiene.

When bacteriology finds its true place in the curriculum of the secondary school, the curves of death, of sickness and of suffering will show a downward tendency, unprecedented in the history of civilization.

FOREIGN AUTOMOBILE TRUCKS.*

By EMILE GUARINI.

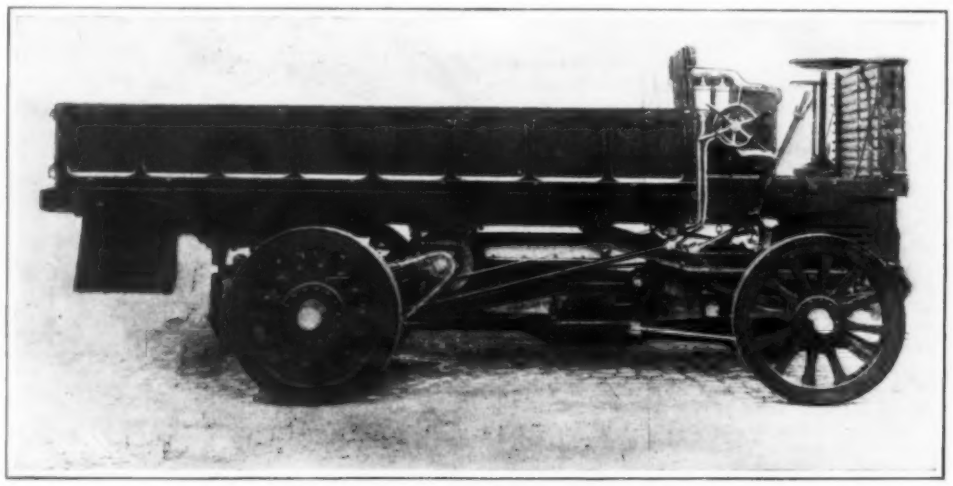
AUTOMOBILE trucks formed one of the great attractions at the Belgian Automobile Exhibition. Such trucks have come into very wide use for industrial purposes in Belgium, especially in the Ardennes. The reason for this is that certain makes of automobile trucks give a saving of about 35 per cent, including interest and cost of maintenance of the vehicle, over animal traction. The cost of a ton-kilometer is 0.31 franc ($0.059, or $0.098 per ton-mile) with horses, and 0.19 franc ($0.036, or $0.06 per ton-mile) with the automobile truck. In order for this economy to become apparent, a considerable quantity of goods must be carried. Trucks for light loads are not as advantageous. They are expensive to run and maintain, and are rather inferior as to efficiency. The fuel for running trucks of from 10 to 12 horse-power costs five or six francs ($1 to $1.20) a day. The trucks can, for the most part, be run very satisfactorily upon low-priced heavy oils, such as kerosene, and the use of ordinary gasoline, such as is used in touring cars and pleasure vehicles and which is much more costly, is not necessary.

Delivery of merchandise by horses is not practical beyond the maximum radius of 15 kilometers (9.31 miles). For greater distances recourse is generally had to railroads or trolley lines for the delivery of goods, and this necessitates two handlings of the merchandise. With automobile trucks, on the contrary, merchants can deliver directly within a radius of 40 or 50 kilometers (24.84 or 31.05 miles), and there are numerous advantages in this. The merchandise is received by the purchaser without any intermediate handling, and it is delivered with great economy of time, responsibility, etc., and without being damaged by the handling which is usually given it. Moreover, the purchaser finds it preferable to have the goods delivered by the employes of the firm and in the firm's delivery wagons rather than by outside express companies, which often deliver the goods in a damaged condition and yet do not accept responsibility or pay any damages.

As with a radius of action tripled (45 kilometers, or 27.9 miles, instead of 15 kilometers, or 9.3 miles) the area of the circle corresponding to this radius is nine times greater, one can easily see the extension of delivery service made possible by automobile trucks. These trucks do not have, moreover, the drawbacks of animal traction, such as the health of the horses—these animals are liable to injuries from falls, various sickness, sudden death, or death from epizootic, which sometimes kills all the horses in a stable—and the necessity of regularly grooming them and hitching them to the wagons, as well as the indispensable and frequent periods of rest which make it impossible to deliver from any center to beyond the very small radius of 15 to 20 kilometers (9.3 to 12.4 miles).

Automobile trucks have the following prime advantages: Constant and regular speed, not requiring any periods of rest, neither after climbing hills nor after being replenished with supplies; the possibility of a mean speed of from 11 to 15 kilometers (6.8 to 9.3 miles) per hour, while the ordinary truck horse cannot go at a greater mean speed than 3½ kilometers (2.17 miles) per hour; the possibility of delivering within a radius of 40 or 50 kilometers directly and rapidly without any second or third handling of the goods; and the possibility of increasing the amount of work on busy days, the mechanical motor not feeling the fatigue and always operating while it is supplied with fuel.

Our illustrations show a few of the foreign trucks which were exhibited at the show in Brussels. The Neue Automobil-Gesellschaft exhibited a two-cylinder, 14-horse-power truck capable of carrying a useful load of 6,000 kilogrammes (13,227 pounds). A truck of similar construction and of the same horse-power is employed by the power station at Berlin, being used daily for carrying coal a distance of 4 kilometers (2½ miles), which it traverses in 20 minutes. This truck makes 9 to 12 trips daily and does the work of four or five horse-drawn coal trucks. These trucks are built in three sizes of 6, 10, and 14 horse-power, capable of carrying respectively loads of from 1,500 to 2,000 kilogrammes (3,306 to 4,409 pounds), 3,000 to 3,900 kilogrammes (6,613 to 8,597 pounds), and 5,000 to 6,000 kilogrammes (11,023 to 13,227 pounds). The space occupied by the first size of truck is 4.5x1.65x1 meters (14.76x5.41x3.28 feet, or 261.9 cubic feet). The space in the body for carrying the load is 2.25x1.65 meters (7.38x5.41 feet, or 39.93 square feet). The tread of the rear wheels is 1.5 meters (4.92 feet). The space occupied by the body of the second type is 5.5x1.8x1.05 meters, the loading space is 3x1.8, and the tread of the rear wheels is 1.5. For the third type the above figures are respectively 6x2x1.10 meters, 3.5x2 meters, and 1.38 meters. The three types of machines have speeds of 2, 5, 8, and 12 kilometers per hour and a reverse. They can ascend a grade of 10 per cent.



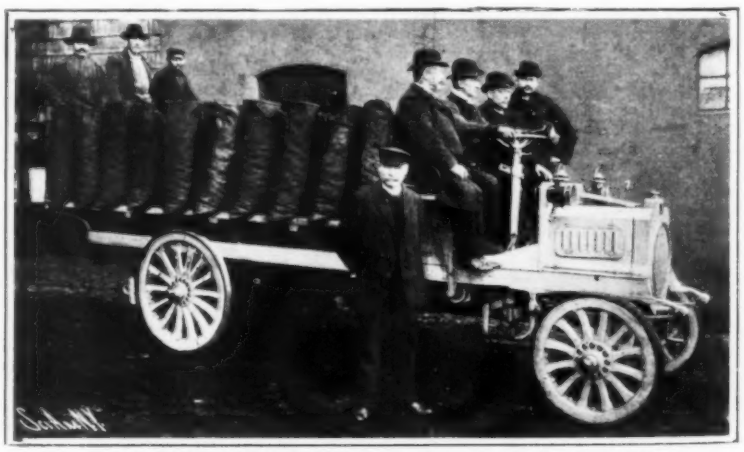
"LA LOCOMOTRICE" AUTOMOBILE TRUCK.

The chassis is of very rigid construction. The two-cylinder, vertical, four-cycle motor is placed at the front of the frame. All the movable parts are incased in oil-tight cases, and all bearings are of the ball type and can be moved without disturbing the motor, by unscrewing several screws. The mean speed of the motor is from 650 to 750 R.P.M., but the motors can be slowed down to 250 and can be speeded up to 1,000 R.P.M. A single pipe carries oil to the crank case of the motor, and all the bearings, as well as the pistons and wrist pins, are oiled by splash lubrication. Each motor is provided with an arrangement for controlling the level of the oil, and also with a device for equalizing the air pressure in the crank case.

The magneto employed for ignition generates a current of constant intensity, while the spark can be considerably advanced or retarded. Things are so arranged that it is impossible for the motor to kick back. The motor is water-cooled with the aid of a radiator and fan driven from the crankshaft. There is no water tank or flanged radiating coils. The total length of the water system piping is only 1 to 1.5 meters (3.28 to 4.92 feet), according to the size of the motor. The quantity of water necessary does not exceed 1 liter (0.26 gallon) per horse-power. The motor evaporates from ½ to 1 liter of water in ten hours' running. The cooling action of the water can be regulated according to the season of the year. The motor is run on alcohol or gasoline. For running on alcohol, the carbureter is double, so that the motor can be started on gasoline and can be switched over to run on alcohol by simply turning a two-way valve. A special vaporizer considerably

*Specially prepared for the SCIENTIFIC AMERICAN SUPPLEMENT.

BELGIAN AUTOMOBILE DUMP TRUCK.



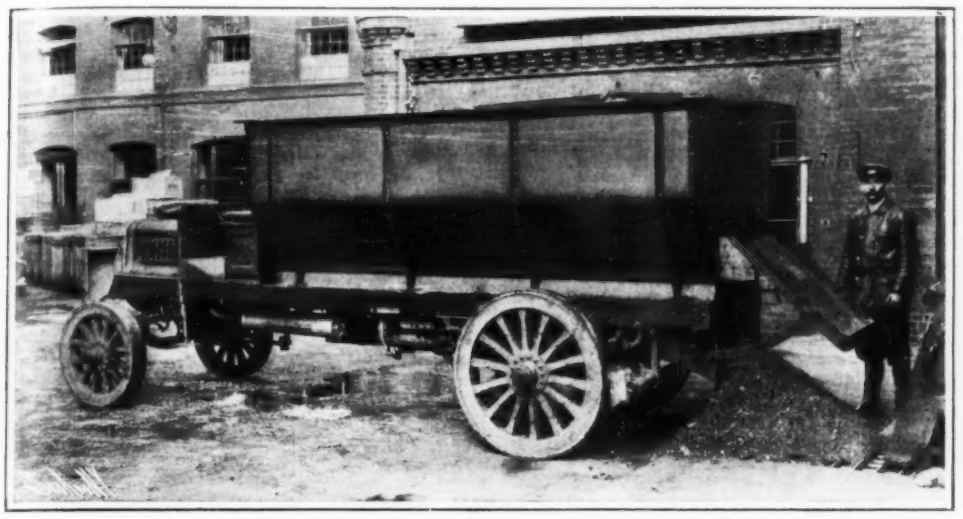
A GERMAN PLATFORM TRUCK LOADED WITH BAGS OF COAL.

EXAMPLES OF FOREIGN AUTO-TRUCKS.

reduces the consumption of alcohol. The admission of air is regulated automatically.

The tank contains sufficient fuel for 100 to 150 kilometers (62 to 93 miles). The fuel is fed to the carburetor automatically by gravity. For running on alcohol, an extra gasoline tank of 5 to 8 liters (1.3 to 2.1 gallons) capacity is necessary for carrying the fuel for starting the motor.

The motor is regulated by means of a throttle. The power of the motor is transmitted through a very elastic radial clutch, the parts of which are well balanced and thus suppress the axial pressure on the bearings of the motor and of the transmission. All the bearings of the transmission are of the ball type and of specially fine construction so as to reduce friction to a minimum. The final drive is from a counter-shaft by chains to the rear wheels, as this is considered the best for heavy-weight vehicles. All the trucks have a pedal for throwing out the clutch and a second pedal for applying the brakes and simultaneously throwing out the clutch of the motor. There are three methods of braking employed. The first consists of throttling the motor, and this is the more energetic in proportion as the speed of the motor is greater. A foot brake and a hand brake can stop the truck in a few meters.



AUTOMOBILE COAL WAGON DUMPING ITS LOAD.

For motors using gasoline the consumption is from 0.4 to 0.68 kilogramme of gasoline per horse-power, while for those using alcohol it rises to 0.6 kilogramme for 90 per cent alcohol mixed with 10 per cent of benzol. Per ton-kilometer total weight, the expense of running is about 2.5 pfennig for the first type, 2.25 for the second type, and 2.1 for the third type. The equivalent cost per ton-mile is 16.64 cents, 15 and 14 cents respectively.

RECEIPTS FOR TREATMENT OF STEEL, COPPER, AND OTHER METALLIC OBJECTS.

CLEANING of Steel.—There are various receipts and processes for cleaning steel, and it is well to understand them, for apparatus and other objects of steel cannot be kept in good condition except by attending carefully to cleaning them. One of the most effective and most rapid (since time is an important factor in the final success) is to smear the object with oil, preferably petroleum, and allow some days for penetration of the surface of the metal. Then rub vigorously with a piece of flannel or willow wood. Success is also assured by rubbing the metallic surface with a paste composed of olive oil, sulphur flowers, and tripoli. Recourse may also be had to similar paste composed of rotten-stone and oil. Finally, a coating may be employed, made of ten parts of potassium cyanide and one part of cream of tartar; or 25 parts of potassium cyanide, with the addition of 55 of carbonate of lime and 20 parts of white soap.

To Remove Rust from Burnished Steel.—Pour olive oil on the spots and leave for several days; then rub with emery or tripoli, without wiping off the oil as far as possible, or always bringing it back on the spot. Afterward, remove the emery and the oil with a rag, rub again with emery soaked with vinegar, and finally with fine plumbago on a piece of chamois skin.

Bronzing of Iron and Steel.—In factories of chemical products it is very difficult to preserve the luster of the metallic parts of machines, on account of the acid vapors which tarnish them notwithstanding lubrication. In some factories the machines are only rubbed with a greasy cloth. At length there is formed a sort of patina, which gives to the pieces a brown, bronze color of agreeable appearance and requiring no further care. When more rapid bronzing is desired, as in the case of a new machine, vessels containing fuming chlorhydric acid and others containing ammonia are merely left in the rooms. The vapors disengaged act on the iron with much rapidity, and in a few days the exterior parts of the machine are bronzed.

Method of Distinguishing Iron from Steel.—The piece of metal to be tested is washed and then plunged into a solution of bichromate of potash, with the addition of a considerable quantity of sulphuric acid. In half a minute or a minute the metal can be taken out, washed and wiped. Soft steels and cast iron assume under this treatment a regular ash-gray tint. Tempered steels become almost black, without any metallic reflection. Puddled and refined irons remain nearly white and always have metallic reflections on the part of their surface previously filed, the remainder of the surface presenting irregular blackish spots.

Burnishing of Magnetic Iron.—Iron may be protected by covering it with a layer of ferroso-ferric oxide. A similar protecting coating may be obtained by heating the iron in air after covering it with linseed oil; the oxide is then mixed with charcoal. Objects not supporting a high temperature are left in acidulated solution of ferric chloride. Then a layer of ferroso-ferric oxide is produced, which is rendered adherent by immersion in hot water and after desiccation the objects are rubbed with linseed oil or wax.

Preparation of Magnetic Oxide.—A layer of magnetic oxide is a good preservative from rust. To obtain it the objects are placed in the furnace at a temperature sufficient for decomposing steam. Steam heated to 600 deg. C. is then injected for from four to six hours. The thickness of the layer of oxide formed varies with the duration of the operation. This process can replace zincing, enameling, and tinning.

The deposit of magnetic oxide may also be obtained by electrolysis. The iron object is placed at the anode in a bath of distilled water heated to 80 deg. C. The cathode is a copper plate, or the vessel itself, if it is of iron or copper. By the electrolysis a layer of magnetic oxide is formed. Other peroxides may be deposited in the same manner. With an alkaline solution of litharge, a very adherent, brilliant, black deposit of peroxide of lead is secured. Too energetic a current must be avoided, as it would cause a pulverulent deposit. To obtain a good coating it is necessary, after putting the objects for a moment at the positive pole, to place them at the other pole until the oxide is completely reduced, and then bring them back to their first position.

Black for Polished Iron Pieces.—Apply successive layers of a very concentrated solution of nitrate of manganese dissolved in alcohol over a gentle fire and the water bath. The surfaces to be blackened should be previously heated. By repeating the layers all the tints between brownish black and bluish black may be obtained.

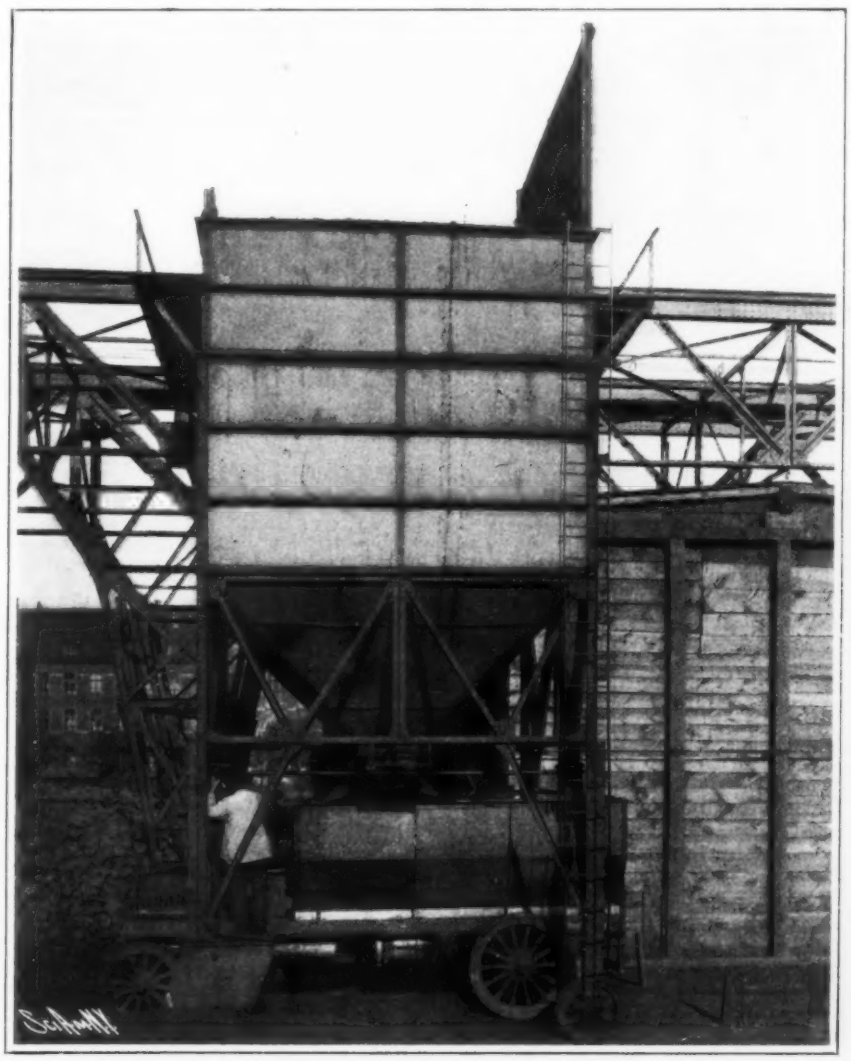
Solvent for Rust.—It is often difficult and at times impossible to remove the rust from certain objects of iron. The cleaning of the pieces may be secured with great facility by their immersion in a nearly saturated solution of chloride of tin. The length of stay in the bath should be proportioned to the thickness of the layer of oxide. In general, from ten to twenty-four hours are sufficient. The solution ought not to contain a great excess of acid; otherwise the iron itself will be attacked. On taking from the bath the objects are first to be rinsed in water, then in ammonia, and rapidly dried. Thus treated, they may appear dull, but simple polishing will restore their normal appearance.

Process for Nickeling Without Battery.—This consists in preparing a bath of neutral zinc chloride and a neutral solution of a nickel salt. The objects are immersed in the bath with small pieces of zinc and kept boiling for some time. This process has given satisfactory results. It is easy to prepare the zinc chloride by dissolving it in chlorhydric acid, as well as a saturated solution of ammoniacal nickel sulphate in the proportion of two volumes of the latter to one of the zinc chloride. The objects ought to be boiled for fifteen minutes in the bath. The nickel salt may also be employed, preferably in the state of chloride.

Coppering of Aluminium.—Make a bath of cupric sulphate, 30 parts; cream of tartar, 30; soda, 25; water, 1,000 parts. After well scouring the objects to be coppered, immerse in the bath.

The coppering may also be effected by means of the battery with the following mixture: sodium phosphate, 50 parts; potassium cyanide, 50; copper cyanide, 50; distilled water, 1,000 parts.

Bronzing of Copper.—Apply to the copper object a solution composed of carbonate or chlorhydrate of ammonia, 30 parts; sea-salt, 10; cream of tartar, 10; acetate of copper, 10; dilute acetic acid, 100 parts.



LOADING AN AUTOMOBILE COAL WAGON.

EXAMPLES OF FOREIGN AUTO-TRUCKS.

Let dry for twenty-four or forty-eight hours at the ordinary temperature. The surface of the metal will then be covered with varied tints. Apply a waxed brush. The green parts, soaked with chlorhydrate of ammonia, will assume a blue coloration; those treated with the carbonate will be strengthened and darkened.

Varnish for Copper.—For protecting the surface of polished copper objects a varnish composed as follows is suitable: 110 parts of sandarac and 30 parts of resin, dissolved in sufficient quantity of alcohol; 5 parts of glycerine are to be added.

Solder for Steel.—Borax, 3 parts; colophony, 2; ground glass, 3; steel filings, 2; carbonate of potash, 1; soap in powder, 1 part. The whole is melted in an earthen or iron pot, run on to a cold plate, and after cooling broken and pulverized.

Solder for Aluminium.—The use of aluminium is quite limited because of the difficulty experienced in soldering it to itself or other metals. The following is recommended. The pieces to be soldered are to be tinned, but instead of using pure tin, alloys of tin with other metals are employed, preferably those of tin and aluminium. For articles requiring to be worked after soldering, 45 parts of tin and 10 parts of aluminium afford a good alloy, malleable enough to be hammered, cut or turned. If they are not to be worked, the alloy requires less aluminium, and may be applied in the usual manner as in soldering iron.

Very Fusible White Solder.—Copper, 57.4 parts; zinc, 28.00 parts; tin, 14.6 parts.

Semi-white Fusible Solder.—Copper, 44.6 parts; zinc, 49.9; tin, 3.3; lead, 1.2 parts.

Soft Solders.—

	p. c.	p. c.	p. c.
Copper	69.5	77.5	77.5
Zinc	18.5	17.5	22.5
Tin	12.	5.	

Soldering Without Heat.—For soldering objects without heating take a large copper wire filed to a point; dip into soldering water and rub the parts to be soldered. Then heat the copper wire and apply the solder, which melts on contact. It may then be applied to the desired spot without heating the object.—Translated from Science Pratique.

[Concluded from SUPPLEMENT No. 1524, page 24419.]

THE THEORY OF THE INCANDESCENT MANTLE.

By VIVIAN B. LEWES, Professor of Chemistry, Royal Naval College, Greenwich.

IN 1898, Le Chatelier and Boudouard published a paper in the Comptes Rendus, in which they claim that the luminosity of mantles may be explained by the ordinary laws of radiation, and from data obtained by heating a flattened thermo-couple coated with various oxides, and noticing the radiations as compared with those given by melting platinum as unity, they conclude that the substance of the mantle possesses at its working temperature an unequal emissive power for the different kinds of rays; it is, therefore, to be regarded as at that temperature a colored body. Its useful incandescence results from the fact that its very high emissivity, near to unity, for blue, green, and yellow rays, is less for the red, and doubtless still more feeble for the ultra-red. The proportion of energy radiated as visible rays is consequently very high; nevertheless, the absolute amount of energy radiated as light is smaller than that which would be diffused by a black body raised to the same temperature. But a black body heated under the same conditions, and with the same area of radiating surface, would attain only a very much lower temperature, and would also have only a very low illuminating power.

In 1900, Professors Nernst and Bose also concluded that the high illuminating value of the mantle could be explained solely by selective radiation of the Welsbach mixture, at the temperature of the Bunsen flame, and in order to ascertain whether the flame gases have any specific effect upon the emission of light by a Welsbach mantle, the two experimenters endeavored to find out whether there was any difference between the radiations from a Welsbach mantle fiber heated in the usual way and those from a similar fiber heated by an electric current. At equal temperatures the radiations were found to be almost identical with thin fibers. Thicker rods brought about differences, which could, however, be simply explained through the heating by the flame being from without, while that by the current was from within. The following table gives the data of this comparison:

Wave lengths.	Flame heating.	Electric heating.	Ratio.
688	0.770	0.790	1.03
589	1.000	0.987	0.99
516	1.36	1.37	0.99
477	2.39	2.34	0.98
447	4.21	4.09	0.97

In conclusion, they give their theory as follows: Since the substance of the mantle emits but little red light or ultra-red rays, and thus gives off but little energy in the form of heat, the mantle can, therefore, completely absorb the high temperature of the gas flame, and, in consequence, emit a relatively greater amount of light.

In 1902, Messrs. White, Traver, and Russell, of the University of Michigan, published a paper on the "Theory of the Incandescent Mantle," which was supplemented later in the year by another on the same subject by White and Traver. In these papers they describe the experimental determination of the temperatures existing in the mantles, and in the flame heating them, by means of the Le Chatelier thermo-couple, and experimented with a pure thoria mantle as well as with one of the ordinary Welsbach mixture. They found that the pure thoria mantle attained a temperature of 1,510 deg. C., and had an illuminating value of 1.2 candles per cubic foot, while the Welsbach mantle only reached a temperature of 1,404 deg. C., and gave 15.7 candles a foot, which they point out is in direct contradiction to the theories of Nernst, Le Chatelier, and their pupils, who hold the illumination of the mantle to be a function of temperature alone. They then repeated the experiments, using pats of ceria, thoria, and the mantle mixture, in which thermo-couples were imbedded, and found that the highest temperature was attained in all experiments from pats of pure thoria, which emitted no light, a result in direct contradiction to Le Chatelier, who found that a couple coated with Welsbach mixture attained a higher temperature than one coated with thoria alone, and it was upon this that he founded his theory. The authors conclude that the exceptional efficiency of the Welsbach mixture is due to a solid solution of ceria in the thoria, and that it has the power of transforming the heat of the flame into light more economically than any other substance yet known.

This paper is of exceptional value on account of the care taken by the authors in proving that fair relative values of mantle temperature can be obtained by judicious use of the thermo-couple, and also for the first recognition of the fact that the thoria mantle is at a higher temperature than the Welsbach mantle. There are, however, two or three weak points in the paper, while the conclusion carefully avoids the point at which all the theorists break down, i. e., why 0.5 to 1.5 per cent of ceria and no other proportion should have the wonderful effect it possesses of awakening the light-giving power of the mantle.

In taking the mantle temperatures, they employ a burner intended for use with a chimney, and as the latter interferes with the manipulation of the thermo-couple, they discard the chimney. This does away with the draft round the mantle, and instead of the flame burning as it should on the surface of the mantle, it has its outer zone of combustion thrown outside the mantle, and that this is so is shown by the Welsbach mantle only giving 15.7 candles per cubic foot of gas instead of 19, as it would have done probably with a chimney on. Under these faulty conditions they take the temperatures of the mantle and the hottest part of the flame outside it, and find the flame considerably hotter than the mantle. Realizing that the conditions are not normal, they then use forced draft, and get results of the same character, but here again the conditions are not those existing with the burner used as intended, and the soft combustion on the surface of the mantle essential for the best results would not be obtained.

Dr. Killing, in 1903, attempted to solve the problem of the mantle by measuring the relative heat radiations of pure thoria mantles and Welsbach mantles in the Junker calorimeter, and found that the addition of 1 per cent of ceria to a mantle increased the heat radiated by 14 per cent, and confirmed this figure by direct thermometric measurements, and he concludes from this that ceria in the Welsbach mixture displays a specific power of increasing the radiation of the mantle.

In 1903, Dr. Bunte read a paper before the Chemical Meeting in Berlin, in which he formally renounced the catalytic theory, and adopted the theories of Nernst and Le Chatelier, on the strength of experiments made under his direction by Dr. Eitner and Herr Schmidt. Eitner first determined the temperature of various points on the surface of a naked Bunsen flame, and then, having put a Welsbach mantle on it, took the temperatures at the same heights above the burner head as those at which the temperatures of the flame had been determined, and found that the flame was considerably hotter than the mantle.

Experiments in which the temperatures of the atmospheric burner flame burning without a mantle are compared with the temperature of the mantle at the same heights above the burner mouth, are absolutely fallacious and useless for two reasons. In the first place, a simple observation of the shape of the flame and of the mantle shows at once how different they are, and that, with the exception of the first few millimeters at the base, the flame and mantle could not be in contact unless the presence of the mantle altered the shape of the flame to a considerable degree, which would also alter its temperature; and, in the second place, in all ordinary atmospheric burners the uprush of the gas in the suction tube draws in the air necessary for the primary actions which give the inner zone to the Bunsen flame, and when the burner is working without a mantle this is arranged to give as hot a flame, i. e., as large a proportion of air to gas as the structure of the burner will allow. The moment, however, that the mantle is put on, the heated structure throws a back pressure on the current of gas and air, which in no way affects the gas, which is driven forward by the pressure in the mains at the same rate as before, but entirely acts in reducing the air supply, which at once falls by 12 to 30 per cent. in quantity, according to the burner used.

This has given rise to many fallacious ideas as to what burners are really doing as regards aëration, some high power burners being claimed to give the full ratio of 6 of air to 1 of gas, while, in fact, the ratio is not much more than half that amount. Some years ago I showed that the best mixture of air and gas, i. e., that which gave the maximum illumination from a mantle, was for gas of the quality of London gas 5.25 to 1, and within the last year this has been confirmed by Herr Winkler, who gives 5.3 to 1; but such proportions are only attained where both air and gas are either under pressure or suction, and if the ratio of air is increased above this point the light from the mantle falls, unless the burner be converted into what is practically a blast blowpipe. For example, a Lucas lamp is claimed to give over 6 of air to 1 of gas, and does so if tested without a mantle, but directly it is tested with a mantle burning under normal conditions, it is found that the ratio is under 5 to 1.

It is clear, therefore, that such tests as those made by Dr. Eitner are worthless as showing the relation between the temperature of the mantle and the flame, or proving that the mantle is cooler than the flame which heats it.

Herr Schmidt made spectro-photometric investigations on thoria-ceria mixtures at various temperatures, and found that the higher the temperature the bluer becomes the light yielded by thoria, while the same thing is observed with mixtures of the two oxides all the time the ceria is below 0.5 per cent. From 0.5 to 1.5 per cent of ceria the red rays and illuminating power increase, but beyond that percentage the color approaches nearer to pure ceria, and the illuminating power decreases. These two sets of experiments led Dr. Bunte to adopt the theory that the lighting effect of the mantle is mainly a consequence of its selective radiation, and to discard his previous belief in catalytic action, owing to Eitner's experiments showing the mantle to be cooler than the flame.

Certainly, one of the most valuable and complete researches on the mantle is that by M. Chas. Fèry, published at the close of 1902, and the conclusion he arrived at is that a mantle of cerium gives no light because it has so great a power of heat radiation that it is impossible to raise its temperature sufficiently in a flame (the temperature of which is limited by the phenomena of dissociation) to endow it with the power of giving light. When, however, the ceria is sufficiently attenuated by sub-division in a thoria mantle, it can be raised to the required temperature, and the light of the Auer mixture is the result.

In 1903, M. E. Sainte-Claire Deville published some experimental results on mantles which led him to support the theory enunciated by Fèry, and a number of experiments have been made in the laboratories at Greenwich during the past few months, the general results of which I will state here, but full details of which I hope to publish shortly.

When mantles of thoria, ceria, and various mixtures of the two are made of exactly the same size and shape, which can be done by using a Buhlmann burning-off apparatus, and when these mantles are tested in a properly regulated Kern burner so as to avoid the use of a chimney, all conditions being kept exactly the same for each, it is found that the flame only extends a millimeter or two beyond the mantle, and that the thoria and 99 per cent thoria with 1 per cent ceria are the only mantles that are heated to a temperature slightly higher than is found in the flame 1 millimeter from the surface of the mantle. The temperatures of the mantle and flame, however, vary enormously with the character of the mantle, and the following table gives the mantle temperature and flame temperature taken 6 millimeters above the rim of the burner, a point at which the mantle is just free from disturbing elements, and where the maximum light is being emitted. There is also given a relative radiation value for the mantles obtained by a thermopile at a fixed distance from them, all measurements being taken with every possible precaution to insure accuracy.

The thoria was not absolutely pure, containing 0.1 per cent ceria, so that the mantle gave 3.4 candles per cubic foot of gas consumed instead of 0.5, and this probably makes the radiation value higher and the mantle temperature lower than it would be for pure thoria.

	Thoria, 99.9 per cent. Ceria, 0.1 per cent.	Thoria, 99 per cent. Ceria, 1 per cent.	Thoria, 90 per cent. Ceria, 10 per cent.	Ceria.
Temperature of mantle 6 m.m. above burner rim	1610	1570	1335	1125
Temperature of flame 1 m.m. from mantle in same spot	1590	1560	1350	1130
Average temperature of mantle up to height of 52 m.m. from burner	1468	1441	1209	1020
Average temperature of flame over same zone	1430	1439	1234	1032
Illuminating power, candles per cubic foot of gas	3.4	20.0	3.3	nil
Radiation value	140	152	218	234

The conclusions which appear to me clear from these figures and the various experiments I have described are that the thoria, owing to its non-conductivity due to its porous condition, its low specific heat, and low radiation power for heat, can be raised to the temperature of the flame, while catalytic action on the still unburnt flame gases and air raises it a few degrees even above this point. Ceria when added in quantities up to 1.5 per cent by weight, or 0.15 per cent by volume, does not interfere with these conditions, but by its still higher catalytic powers tends to focus the combustion of the extremely attenuated combustible constituents of the flame gases on the widely distributed

ceria particles, and by this localization raise them to a far higher temperature than the mantle, a temperature, however, which cannot be detected by the thermo-couple, which only gives the average temperature of the mass with which it is in contact, and fails to show the temperature of the 0.15 per cent of ceria. Addition of more ceria to the mixture causes such a rapid cooling of both mantle and flame by radiation that the light at once begins to fall, and by the time 10 per cent of ceria is in the mixture, the mantle gives us no more light than a thoria mantle, but a much increased heat radiation.

As to the portion of the spectrum to which the light waves emitted by the ceria at the temperature attained by the finely divided particles in the mantle belong I have no personal knowledge, and am quite prepared to accept the evidence adduced by Le Chatelier, Nernst, Schmidt, and others, in which case catalysis, temperature, and selective radiation all play their part in bringing about that wonderful light emissivity which has made the incandescent mantle the savior of the gas industry.—Chemical News.

SIMPLE EXPERIMENTS IN HYGIENE.*

By LILLIAN CHAPIN, B.S., Instructor Calumet High School, Chicago.

HYGIENE is the one secondary school subject that every pupil will find necessary throughout life. Yet, in few high schools and normal schools has it received the treatment a subject of such importance demands. This article is a plea for definite, forceful experiments and demonstrations in this subject, comparable with the experiments and demonstrations so long deemed essential in physics and chemistry. The following are experiments of this nature that could be carried out in any secondary school.

1. *To demonstrate bacteria in the air.*—If it were possible to find a transparent solid substance upon which germs would multiply, this substance might be exposed to the air and bacteria allowed to settle on it. On multiplying, there would develop about each bacterium a group or colony of bacteria, which colony might, in time, become large enough to be visible to the naked eye. Several such "culture media" have been devised by bacteriologists. The one selected for this work was nutrient agar, a jelly-like material made from sea-weed.† This medium is conveniently stored in test-tubes, each containing enough for a single experiment. For the work here reported about 5 cubic centimeters of melted agar was placed in each tube. The tubes were plugged with cotton and rendered free from living organisms by heating in a steam sterilizer.

The only other article needed for this experiment is a flat glass dish with a glass cover, the so-called Petri dish. A number of these dishes were cleaned, dried, and heated in an oven to render them free from living germs.

A test-tube of agar was melted by immersing it in boiling water. The agar was then poured out into a Petri dish where it soon solidified in a thin layer. The cover of the dish was now removed and the agar exposed to the air for a number of minutes. The cover was replaced and the dish set aside to develop. Two days later, it contained 63 colonies of bacteria, while a Petri dish prepared in the same way but not exposed to the air developed no colonies.

2. *To demonstrate bacteria in water.*—A test-tube of agar was melted and then placed in water at 42 deg. C., a temperature slightly above that of the human body. At this temperature, agar remains liquefied, but is not hot enough to kill bacteria. Two tiny drops of drinking water, each less than a millimeter in diameter, were transferred to this liquid agar by means of a small loop of platinum wire. The agar was then poured into a sterile Petri dish. The dish was put aside and a few days later was found to contain fourteen colonies of bacteria, each colony representing a bacterium present in the original drops of water.

3. *To demonstrate bacteria in milk.*—In the same way, two tiny drops of milk were inoculated into agar and the agar poured into a Petri dish. In this dish 192 colonies developed.

4. *To determine the effect of heat upon bacteria.*—Three test-tubes of milk were taken. The first was kept at room temperature, the second was immersed in water heated to 60 deg. C., and the third was placed in boiling water. At the end of about twenty minutes, tiny drops were taken from each sample and Petri dishes prepared in the manner described above. The number of colonies developing on each of these dishes is shown below:

Unheated milk	192 colonies
Milk heated to 60 deg. C.	13 colonies
Milk heated to 100 deg. C.	5 colonies

In the process of pasteurization, milk is heated to 60 deg. C. for half an hour. This is sufficient to kill all the more common disease germs, but not sufficient to kill some of the more resisting, harmless bacteria.

5. *To demonstrate the effect of freezing on bacteria.*—Two test-tubes of water were taken. One was kept at room temperature. The other was immersed in a freezing mixture of salt and ice and frozen solid. At the end of twenty minutes it was removed from the freezing mixture and allowed to melt. Petri dishes were then prepared from each with the following counts:

Not frozen	272 colonies
Frozen	294 colonies

In a similar experiment performed with milk, 192 colonies developed from the sample kept at room temperature, and 193 colonies from the samples frozen.

From these experiments, we see that bacteria are probably unaffected by ordinary freezing, the differences noted above being presumably due to variations in the size of the drops taken.

6. *To show the effect of temperature on the rate of multiplication of bacteria.*—Three test-tubes of milk were taken. A Petri dish made from the milk at this time showed 80 colonies of bacteria. The first was placed in an ice chest, the second was kept in a locker, and the third was put in a thermostat at 37 deg. C. The next day Petri dishes were made from each tube, with the following results:

Ice chest (4 deg. C.)	70 colonies
Locker (20 deg. C.)	30,000 colonies
Thermostat (37 deg. C.)	100,000 colonies

7. *To determine the effect of drying on bacteria.*—Three tiny drops of beef broth in which typhoid fever germs* were growing, were transferred to each of two dry, sterile test-tubes. Into the first tube, melted agar was poured, and then poured out into a sterile Petri dish. The drops in the second tube were allowed to dry, and two days later a Petri dish was prepared from this tube in the same way. In the first dish 6,000 colonies grew. No colonies developed from the dried specimen.

Drying kills many disease germs, but some of them, e. g., the tubercle bacillus, can resist drying for a long time.

8. *To determine the effect of sunlight on bacteria.*—Two slips of filter paper were wet with a beef-broth culture of typhoid bacilli. The papers were placed in dry test-tubes. The test-tubes were sealed with paraffine to prevent drying. One of the tubes was placed in a locker. The other was exposed to sunlight for three hours. The papers were then removed, dropped into tubes of melted agar, and the agar poured into Petri dishes. From the paper kept in the locker, 100,000 colonies developed. No colonies grew from the paper exposed to sunlight.

9. *A study of antiseptics.*—Four test-tubes were prepared, each containing 5 cubic centimeters of water to which typhoid bacilli had been added. To the first tube nothing was added. To the second tube ½ cubic centimeter of a weak solution of the antiseptic to be tested was added. To the third, 1 cubic centimeter, and to the fourth 2 cubic centimeters. Twenty minutes later, Petri dishes were prepared from each of these tubes. The number of colonies developing in each is shown below:

Antiseptic	0 c.c.	½ c.c.	1 c.c.	2 c.c.
5 per cent carbolic acid	446	237	95	20
95 per cent alcohol	446	96	25	1
Salicylic acid (sat. sol.)	3,640	298	60	15
1-10 per c't mercuric chloride	3,640	1	0	0

10. *To disinfect a room.*—Three slips of filter paper were moistened in a beef-broth culture of typhoid bacilli. These were placed in sterile test-tubes, and the test-tubes in turn were placed in large glass jars. In the first jar sulphur was burned. Into the second jar, formaline vapor, generated by heating commercial formaline in a distilling flask, was passed. The third jar was not treated with a disinfectant. A few hours later, Petri dishes were prepared from each paper. The results are shown in the table below:

No disinfectant	100,000 colonies
Sulphur fumes	6 colonies
Formaline vapor	0 colonies

11. *To show the effect of food preservatives on the rate of multiplication of bacteria.*—Two test-tubes, each containing 5 cubic centimeters of fresh milk, were taken. A Petri dish made from the milk at this time showed 83 colonies of bacteria. To one of the tubes a grain or two of common salt was added. To the second tube nothing was added. The next day, Petri dishes were made from these tubes with the following results:

No preservative	7,520 colonies
Salt	850 colonies

12. *To show the antiseptic properties of gastric juice.*—An artificial gastric juice was prepared by dissolving a little pepsin in a ¼ per cent solution of hydrochloric acid. To 1 cubic centimeter of this juice, ¼ cubic centimeter of a beef-broth culture of typhoid bacilli was added, and Petri dishes made from the mixture at intervals for half an hour. The number of colonies developing on these dishes is tabulated below. To get an idea of the number of germs originally added to the juice, the same amount of typhoid culture was added to 1 cubic centimeter of sterile water and a Petri dish prepared from this mixture. The number of colonies on this dish is recorded as the count for 0 minutes.

0 minutes	35,200 colonies
2 minutes	157 colonies
15 minutes	3 colonies
30 minutes	0 colonies

13. *To show the antiseptic properties of human serum.*—Under the supervision of a physician, a small amount of blood was drawn, by means of a hypodermic needle, from a vein in the arm. This blood was placed in a sterile glass vessel and allowed to clot. After standing some time, serum separated. One cubic centimeter of this serum was placed in a small test-tube and five loops full of a beef-broth culture of typhoid bacilli were added to it. Petri dishes were made from this mixture at intervals for an hour. To get an idea of the number of germs originally placed in the serum, a control was run with an equal volume of sterile water. The count made from this control is recorded as the count for 0 minutes.

0 minutes	3,760 colonies
2 minutes	737 colonies
8 minutes	410 minutes
15 minutes	34 colonies
30 minutes	2 colonies
60 minutes	0 colonies

14. *Are bacteria given off from a moist surface?*—A culture of harmless, brilliant yellow bacteria was smeared on the inside of a large glass tube. Through this tube, a strong current of air was directed onto agar in a Petri dish. If bacteria were given off into the air from the moist culture, they would be blown upon the agar, where they would develop into colonies. The Petri dish used in this experiment developed no yellowish colonies.

The smear was allowed to dry and was then crushed with a sterile glass rod. A second current of air was now directed through it into another Petri dish. This dish developed 240 colonies of yellow bacteria.

Bacteria are not given off into the air from a moist surface. Tuberculous sputum and other infectious materials are, therefore, comparatively harmless while in a moist condition. The breath of a consumptive is free from germs. This, of course, does not mean that in coughing, or in excited speech, germs may not be thrown into the air in the form of spray.

The above are suggestions of the kind of experiments that might be done with profit in secondary schools. Most of these experiments can be performed by the average high-school senior. All of them can be used as class demonstrations. A few weeks' training in bacteriological technic will enable any teacher to give this work.

These experiments require only the simplest apparatus—a few test-tubes, Petri dishes, and a little platinum wire. A steam sterilizer, which need not cost over $1.25, is the most expensive single article.

I am indebted to Dr. W. H. Manwaring, of the Department of Pathology and Bacteriology of the University of Chicago, for suggestions in regard to a number of these experiments.

* Reprinted from School Science and Math., February, 1905.

† For methods of making and sterilizing media, see any text-book of bacteriology.

* In repeating this experiment in high schools, harmless germs must of course be used. The colon bacillus is recommended for this purpose.

WATERPROOFING OF FABRICS.

THE following are processes used to advantage in the manufacture of waterproof fabrics:

Ordinary Fabrics, Dressing Apparel, etc.—Immerse in a vat of acetate of alumina (5 deg. Bé.) for twelve hours, lift, dry, and let evaporate at a temperature of from 60 deg. to 65 deg. C.

Sailcloth, Awnings, Thick Blankets, etc.—Soak in a seven per cent solution of gelatine at 40 deg. C., dry, pass through a four per cent solution of alum, dry again, rinse in water, and dry.

Fabrics of Cotton, Linen, Jute, and Hemp.—Put into a bath of ammoniacal cupric sulphate of 10 deg. Bé. at a temperature of 25 deg. C.; let steep thoroughly, then put in a bath of caustic soda (20 deg. Bé.) and dry. To increase the impermeability, a bath of sulphate of alumina may be substituted for the caustic-soda bath.

Another method is to saturate the fabrics with the following odorless compound, subjecting them several times to a brushing machine having several rollers, where the warp threads will be well smoothed, and a waterproof product of fine sheen and scarcely fading will be the result. The compound is made with 30 kilogrammes of Japan wax, 22½ kilogrammes of paraffine, 12 kilogrammes of resin soap, 35 kilogrammes of starch, and 5 kilogrammes of a five per cent solution of alum. Fabrics thus prepared are particularly adapted to the manufacture of haversacks, shoes, etc.

White or Light Fabrics.—Pass first through a bath of acetate of alumina of 4 to 5 deg. Bé. at a temperature of 40 deg. C., then through the rollers to rid of all liquid; put into a warm solution of soap (5 kilogrammes of olive oil soap to 100 kilogrammes of fresh water) and finally pass through a two per cent solution of alum, dry for two or three days on the dropping horse, and brush off all particles of soap.

Another method for cotton is the following: Dissolve 1½ kilogrammes of gelatine in 50 liters of boiling water, add 1½ kilogrammes of scraped tallow soap and 2½ kilogrammes of alum, the latter being put in gradually; lower the temperature of the bath to 50 deg. C., lift out the fabric, dry, and calender.

Tent Cloth.—Soak in a warm solution of 1 kilogramme of gelatine, 1 kilogramme of glycerine, and 1 kilogramme of tannin in 12 kilogrammes of wood vinegar (pyroligneous acid) of 12 deg. Bé. The whole is melted in a kettle and carefully mixed. The mass is poured into the receiver of the brushing machine, care being taken to keep it liquid. For a piece of 150 meters in length and 50 centimeters in width, 50 to 80 kilogrammes of this compound are needed.

To freshen worn waterproof material, cover with the following: 5½ kilogrammes of gelatine, 100 grammes of bichromate of potash, 100 grammes of acetic acid (to keep glue from congealing) and from 3 to 5 kilogrammes of water; to this add ½ kilogramme of peroxide of ammoniacal copper 100 deg. Bé. This compound is put on the fabric with a brush and then exposed to air and light.

Soft Hats.—The hats are stiffened as usual, then put through the following three baths: Dissolve ½ kilogramme of tallow soap in from 40 to 50 liters of warm water (60 deg. C.). Put three to four dozen hats into this solution, leave them in it for half an hour.

then take out and put them as they are into another bath prepared with 40 to 50 liters of water and ½ kilogramme of alum and heated to 30 to 40 deg. C. After having been left in the second bath for one-quarter or one-half an hour, take out as before, put into the third bath of 40 to 50 liters of water, ½ kilogramme of alum, and about 30 grammes of fish glue. In this cold bath the hats are left for another one-half hour or more until they are completely saturated with the liquid, then dried and the other operations continued.—Translated from the Deutsche Färber Zeitung.

[Concluded from SUPPLEMENT No. 1523, page 24410.]

EXPERIMENTAL ELECTROCHEMISTRY.*

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NINTH PAPER.

Electrolytic Preparation of Potassium Chlorate from Potassium Chloride.—Preparation of Solid Trioxide of Sulphur.—Production of Ozone from the Atmosphere.—Experiments with Ozone and Its Practical Applications.

Electrolytic Preparation of Potassium Chlorate.

AN outline of the purely chemical method for preparing this important compound should be given before undertaking the electrolytic plan. Potassium chlorate or chlorate of potash is prepared in the chemical way by passing an excess of chlorine gas rapidly into a strong solution of potassium hydroxide. When the liquid becomes hot enough to decompose the hypochlorite first formed into potassium chloride, which remains in solution, the potassium chlorate deposits in tabular crystals. The ultimate result of such a chemical method for this compound may be expressed by the following simple equation:

$$6KOH + Cl_6 = KClO_3 + 5KCl + 3H_2O.$$

If potassium carbonate or a weak solution of potassium hydroxide be employed, the liquid will require boiling after saturation with chlorine, in order to convert the hypochlorite into chlorate. This chemical process for the preparation of potassium chlorate is far from being economical, since five-sixths of the potash is converted into chloride, being employed merely to furnish oxygen to convert the chlorine into chloric acid. In manufacturing potassium chlorate upon a large scale, a much cheaper material is used, namely lime, to furnish the oxygen. The lime is mixed with water, and saturated with chlorine gas in closed leaden tanks, when we obtain the following reaction:

$$2Ca(OH)_2 + 4Cl = Ca(OCl)_2 + CaCl_2 + H_2O.$$

The liquid is boiled down, when the calcium hypochlorite is decomposed into calcium chlorate and chloride:

$$3Ca(OCl)_2 = Ca(ClO_3)_2 + 2CaCl_2.$$

The calcium chlorate is now decomposed by boiling with potassium chloride, when it yields calcium chloride which remains in solution, and potassium chlorate which separates in crystals as the solution cools. The following equation expresses this step in the process:

$$Ca(ClO_3)_2 + 2KCl = CaCl_2 + 2KClO_3.$$

In the preparation of potassium chlorate by electrolytic means, certain difficulties are met with. The simple plan of subjecting a hot solution of potassium chloride to electrolysis, and allowing the free mixing of the chlorine and caustic soda produced, is workable only with low concentrations. The obtaining of the potassium chlorate from an electrolyte containing chloride is a rather difficult matter by means of any process of crystallizing out. Without a porous partition or means of keeping the electrode products separated, the anode or oxidized product will reach the cathode and will there be reduced. At the same time the potassium hydroxide formed at the cathode can serve independently as an electrolyte, yielding at the electrodes oxygen and hydrogen gases, with the useless expenditure of electrical energy. The student in electrochemical processes should be on the lookout for every such possibility and should have such losses in mind in the design and construction of his apparatus. Let us take up the experimental preparation of this most important compound electrolytically in the simplest manner, using first an open beaker glass without porous partitions. The student can make his determinations, and then modify the apparatus with a porous pot with a view to increasing the working efficiency. For the simplest workable plan we will employ an electrolyte of the following composition:

100 grammes of potassium chloride.
1 gramme of potassium carbonate.
1 gramme of potassium dichromate.
250 grammes of hot distilled water.

Fig. 1 shows the arrangement of the necessary apparatus in its simplest form. In making records of experiments in our note books, it cannot be too strongly impressed upon the student to make concise and neat little sketches of the apparatus and the manner in which it was assembled, to be accompanied of course by a full tabulated list of conditions as set forth in a previous chapter. In our first illustration we have a large beaker resting upon a square of asbestos, supported by a low iron ring tripod over a special low type of Bunsen burner for maintaining the electrolyte at an elevated temperature, as is necessary. The anode and cathode are both of sheet platinum, and are most conveniently supported by a couple of electrolytic stands with insulating glass columns as described and recommended in the last chapter. A thermometer is immersed in the electrolyte, together with a glass tube as indicated, through which a current of carbon dioxide

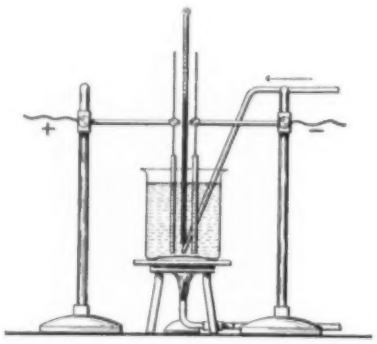

Fig. 1.—Experimental Apparatus for the Electrolytic Preparation of Potassium Chlorate from Potassium Chloride.

gas is passed. The current density at the anode should be at least 20 amperes per 100 square centimeters of immersed electrode, and the current density at the cathode should be about double this for best results. The electrolyte is kept at a temperature of 60 deg. C. and a feeble acid reaction is maintained by a current of carbon dioxide gas, which also keeps the solution agitated and of uniform composition. According to Dr. Karl Elbs, of the University of Giessen, at least 60 ampere hours are necessary for this quantity of electrolyte, since one ampere hour yields 0.75 gramme of potassium chlorate. According to Dr. Elbs, if a separation of potassium chlorate has commenced during the electrolysis, after allowing the electrolyte to cool down, a considerable quantity of potassium chlorate crystallizes out, which is purified by a single re-crystallization. By evaporation of the mother liquor to about one-half its original volume and then allowing it to cool down, a second lot of crystals is obtained. The current efficiency amounts to about 70 per cent of the theoretical, and only begins to fall off to a serious extent if over 50 per cent of the potassium chloride has been converted into potassium chlorate. It is very evident from the foregoing that if the current efficiency be calculated from the amount of potassium chlorate in the crystalline solid form, the figure obtained will be too low because of the quantity remaining behind in the mother liquor. Sodium chlorate may be prepared with the same apparatus by using as an electrolyte:

80 grammes of sodium chloride.
2 grammes of sodium carbonate.
1 gramme of sodium dichromate.
250 grammes of hot distilled water.

The electrical conditions are the same as in the preparation of potassium chlorate and the current efficiency

Fig. 2.—Useful Design of "U" Tube for Conducting Electrolytic Preparations and Maintaining an Elevated Temperature by the Current Itself. The Center Tube Receives the Thermometer.

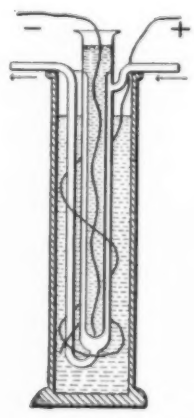

Fig. 5.—Experimental Apparatus for the Production of Ozone from the Atmosphere. Dilute Sulphuric Acid fills both Outside Cylinder and Inner Chamber of the Central Tube.

is also about 70 per cent. The electrolyte in this case is evaporated to a small volume, when the sodium chloride will separate out of the solution and is filtered off. The final product is not pure, being contaminated with sodium chloride and sodium chromate. Sodium chromate is exceedingly soluble, and a complete purification of a small quantity is therefore a difficult matter. Potassium and sodium chlorates may be quickly prepared in small quantities without the aid of external heating by employing a special "U" tube with a center limb like that illustrated in Fig. 2. Because of the comparatively small cross section of the electrolyte, the temperature of the same can easily be kept at the required point by controlling the electric current. The central tube serves for the reception of the thermometer. Such a piece of apparatus not only serves for this particular line of electrolytic work, but is of a generally useful and flexible character. Fig. 3 illustrates such a tube in connection with an ammeter and lamp bank, by means of which electrolytes can easily

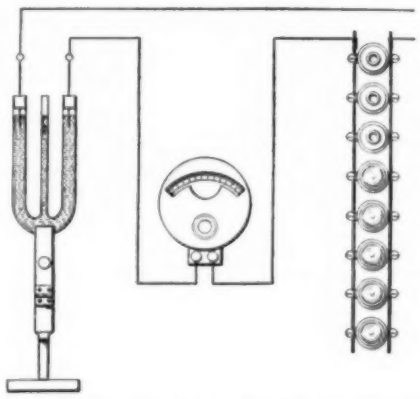

Fig. 3.—Combination of Special "U" Tube with Ammeter and Lamp Bank, Whereby Electrolytes Can be Maintained at their Boiling Points by the Electrolyzing Current. By Means of the Ammeter and the Thermometer Conditions can be Easily Controlled.

be maintained at their boiling points by the electrolyzing current if necessary.

Preparation of Solid Trioxide of Sulphur.

It will be remembered that in a previous chapter the electrolysis of concentrated sulphuric acid was conducted with the liberation of hydrogen, oxygen, ozone, and free sulphur, and at elevated temperatures the electrode products became hydrogen, oxygen, and sulphur trioxide. If now we select a thin glass wolf bottle intended for heating, and subject concentrated sulphuric acid to a process of electrolysis with a heavy current, we will elevate the temperature sufficiently to produce sulphur trioxide in quantity, which may be condensed to a white solid with ease by passing the gas into a suitable condenser. This experiment is not intended to show a method for preparing sulphur trioxide, to compete with any existing chemical schemes, but merely as an exercise of interest in conducting practical work. Fig. 4 shows the arrangement of the apparatus which consists of a thin wolf bottle with platinum electrodes and a thermometer for noting the temperature. There is a glass tube leading to a condenser fitted with stop cocks immersed in a freezing mixture, and a lamp bank for modifying the lighting current. Electrical measuring instruments are shown in this illustration, although the production of this interesting compound upon this plan hardly warrants the setting down of efficiency data. Like the experiment with the cold acid, the experiment is useful in demonstrating the composition of sulphuric acid by electrolytic means. Such a piece of apparatus is very useful in conducting research work upon compounds, the mechanism of which electrolysis is doubtful. For example, in electrolysis we may be obtaining a condensible gas from one of the electrodes, and it would be highly desirable to obtain this gas in a liquid or a solid form for identification. In a certain piece of research work undertaken by the author, oxides of

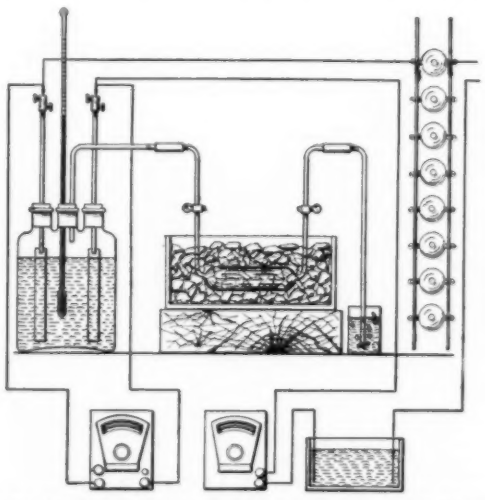

Fig. 4.—Experimental Preparation of Solid Sulphur Trioxide by the Electrolysis of Concentrated Sulphuric Acid.

nitrogen were given off on electrolysis, and it was a convenient operation to pass the electrode gas through such a condenser immersed in liquid air, when the oxides of nitrogen condensed to a light blue solid, and were estimated in this form! Sulphur dioxide, as is well known by all general chemists, can be liquefied by passing it through such a condenser immersed in a simple freezing mixture of ice and salt. It is believed that, apart from introducing an experiment, or a method of preparing a compound, the description of special and useful apparatus will prove as valuable to the

* Specially prepared for the SCIENTIFIC AMERICAN SUPPLEMENT.

With this installment, Prof. Hopkins's series of articles on electrochemistry is concluded in the SCIENTIFIC AMERICAN SUPPLEMENT. For the benefit of those readers who have not read every installment, it may not be amiss to state that the articles have appeared in SUPPLEMENT numbers 1509, 1511, 1513, 1515, 1517, 1519, 1521, 1523 and 1525. Considered as a whole, the series supply a much-needed want in scientific literature; for there is no book to which the student can turn which will give him such valuable help in experimental work in electrochemistry.

experimenter and investigator as many theories and their applications. Having produced a number of typical electrolytic preparations in inorganic chemistry, we would neglect some very important applications of electricity to chemistry, unless we prepared certain important gases of commercial value. Perhaps the first gaseous preparation should be that of ozone, and the following pages will therefore be devoted to this valuable product.

The Electrical Production of Ozone.

Ozone is the chemical name as applied to a peculiar form of oxygen, the exact nature of which is open to some little discussion, as it has been impossible to obtain absolutely pure ozone. It is always accompanied with ordinary oxygen, but there are good reasons for believing that ozone consists of three atoms of oxygen. Three atoms of oxygen, occupying three volumes, therefore, combine to one molecule of ozone which occupies two volumes. Ozone, according to this scheme of formation, would be one-half as heavy again as ordinary oxygen, and experiments upon its rate of diffu-

Fig. 6.—Another Form of Ozone Apparatus Based upon the Same Principle. The Outer and Inner Tubes Contain Dilute Sulphuric Acid. The Inner Tube is Sealed up, only a Small Air Bubble Remaining.

sion go to support this theory. In the year 1785, Von Marum noticed that oxygen, upon being subjected to electrical discharges, acquired an odor like that experienced after the atmosphere had been subjected to an active electrical storm. In 1840, Schoenbein called attention to the similarity between the odors produced when air was treated to electrical discharges, and the odors noticed when water was electrolyzed between platinum electrodes, or gold electrodes, for with the baser metals the production of ozone was not so marked. The production of ozone was probably just as great, only it was largely expended in oxidizing the electrodes when they were not of platinum or of gold. The same investigator also observed that a like odor accompanied the slow oxidation of phosphorus and also of sulphur, and that in each case a piece of filter paper moistened with a solution of starch and potassium iodide was turned blue. About the same time, two other investigators, Marignac, and De la Rive, showed that ozone was only a changed condition of oxygen. In 1852, Becquerel and Fremy demonstrated that pure oxygen could be converted into ozone. In 1860, Andrews and Tait called attention to the fact that a marked contraction in volume accompanied the formation of ozone from oxygen, and in the same year Soret showed that oil of turpentine absorbed ozone completely, and in this way determined its relative density, confirming his results in 1867 by the method based on the rate of the diffusion of gases as already mentioned. Andrews suggested at this time that the substance present in the atmosphere which affected starch and potassium iodide paper was this modified form of oxygen. We have already seen that ozone may be obtained in the electrolysis of concentrated sulphuric acid between platinum electrodes. Is this the most efficient and economical way of producing it? It is not, for there have been designed and put into practice many forms of special ozone generators of greater efficiency. For laboratory purposes the generator as illustrated in Fig. 5 has proven very useful. Here the apparatus is shown in section in order that its several

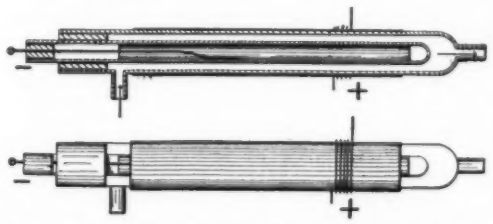

Fig. 7.—Cross Section and Elevation of an Original Siemens Apparatus for the Production of Ozone from Atmospheric Oxygen.
The Sulphuric Acid is Displaced in This Tube by Some Unoxidizable Metal such as Tin Foil.

parts and their relations may be clearly seen and understood. The tall outside cylinder glass is filled with dilute sulphuric acid, one to ten, as well as the inner chamber of the tube which is immersed therein. Two platinum wires are dipped respectively into the acid in the outer glass cylinder, and in the acid in the inner tube. When these platinum wires are connected to the secondary terminals of a good induction coil, the two portions of the sulphuric acid become electrified, and there is believed to be a stress set up which resolves the oxygen molecules into its atoms, with a recombination to form molecules of ozone. Dry air or dry oxygen is passed through the space between the two volumes of acid, which space for most economical action should be as narrow as possible. Another important condition is the temperature of the air or oxygen used. It should be cooled down to a low temperature before sending through, and should not be supplied too fast. Fig. 6 illustrates a special horizontal form of ozone apparatus based upon the same general principle. The longer the tube and the greater the area exposed to the oxygen or air the greater the ozonizing power of the apparatus for a stream of air or oxygen of a given velocity and volume. The ordinary chemical test for ozone, as has been intimated, is a damp mixture of starch and potassium iodide, preferably made into test paper. To make a good test paper for our work with ozone preparation, take 100 grammes of starch and grind thoroughly in a mortar with 50 cubic centimeters of distilled water. The thin paste is then poured into 250 cubic centimeters of boiling distilled water in a beaker, and one-half a gramme of potassium iodide crystals are added and made to dissolve by stirring. Narrow pieces of filter paper are drawn through this solution with glass rods and hung up to dry. When these pieces of paper are moistened, and exposed to ozone, they turn blue, but are not affected by ordinary oxygen. The ozone abstracts the potassium from the potassium iodide, and sets free the iodine, which has the specific property of imparting a deep blue color to starch. Papers impregnated with manganese sulphate, lead acetate, or thallous oxide, become brown, in the first two cases by the formation of the peroxide of the metal, and in the last case from the formation of thallic oxide, under the influence of ozone. Thus it will be seen that ozone is an excellent and energetic oxidizing agent. If ozone is passed into a solution of indigo, the blue color will soon disappear, since the ozone oxidizes the indigo, and gives rise to products which, in a diluted state, are nearly colorless. Ordinary oxygen is not capable of bleaching indigo in this manner. If ozone is passed through a tube of vulcanized caoutchouc, this will soon be perforated by the corrosive effect of the gas, while ordinary oxygen would be without effect upon it. If ozonized air be passed into a flask with a little mercury in the bottom, the surface of the mercury will soon be tarnished as the result of the formation of oxide, and when the mercury is shaken around in the flask, it will adhere to the sides, which will not be the case with pure mercury, as is well known. Let us look into other forms of ozone apparatus and the application of the electricity. Fig. 7 illustrates a simple Siemens tube, which is perhaps the simplest to construct in the laboratory.

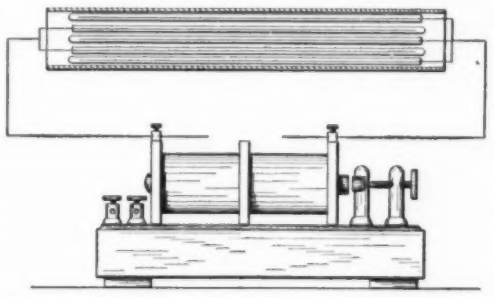

Fig. 8.—Efficient Type of Ozone Apparatus and Induction Coil Assembled for Production.

Here we have merely an inner and an outer tube as shown in the sectional view. The inner tube is held in position by a good cork and is lined on the inside with tinfoil. This tube is closed at one end by sealing off, and at the other end by a cork stopper through which a platinum wire passes and makes contact with the tinfoil lining. The outer tube has a side and end tubulure through which the air or oxygen gas is passed. This outer tube is coated with tinfoil on the outside with which electrical connection is also made. A good induction coil with a condenser of large capacity is employed with this apparatus as with the acid tubes. In a lecture by Froelich he has given an account of the experiments which have been made in the laboratory of Messrs. Siemens & Halske in Berlin for the commercial production of ozone. The original Siemens ozonizing tube was like that illustrated, the two coatings being supplied with an alternating current of high potential, while oxygen was made to traverse the annular space between the two tubes. It appears that only one dielectric is necessary, mica, celluloid, porcelain, and the like being available, as well as glass, and the ozone tube having either a metal tube within and a metal-coated non-conducting tube without, or a metal tube without, while the inner tube is made of the non-conducting material and lined with metal. The metals to be used are of course those which are not attacked by ozone, such as platinum, tin, or aluminium. Cold water flows through the inner tube, and through the annular space pure, dry air. Several such tubes may of course be combined into one system and be worked equally well with the alternating currents, although for single tubes it is stated that direct currents operated by interrupters may be used to advantage. The apparatus as described by Froelich in the German laboratory yields 2.4 milligrammes of ozone per second. Experiments have been made with a view of producing compressed ozone for technical uses, this having already been done on a small scale under a pressure of about ten atmospheres. One use of ozone especially dwelt upon by Froelich is the oxidation of organic impurities in drinking water. Experiments with ozone upon water supplies have been made in this country, nevertheless, for a long time. In all productions of ozone it is very important to keep the temperature low, and the following experiment will serve to impress this fact upon the student: If ozone be made to pass slowly through a glass tube heated in the center by a Bunsen burner, it will be found to lose its power of affecting starch and potassium iodide paper, the ozone having been reconverted into ordinary oxygen under the influence of heat. The formation of ozone may be compared with the production of hydrogen peroxide, and we may presently express this breaking up of ozone symbolically. Just as hydrogen dioxide, H_2O_2, may be regarded as formed by the combination of a molecule of water H_2O, with an atom of oxygen, so ozone may be viewed as a combination of a molecule of oxygen O_2, with an atom of oxygen. The breaking up by heat of ozone may therefore be expressed:

$$2(OO_2) = 3(O_2).$$

A temperature of 250 deg. C. is sufficient to completely bring about this breaking up of the ozone. As we have learned, a given volume of oxygen diminishes when a portion of it is converted into ozone by the silent electrical discharge, and it regains its original volume when the ozone is reconverted by heat. It is of interest to note that the conversion of oxygen into ozone is attended by the absorption of heat; in other words, it is endothermic. The value of this heat absorption may be expressed thus:

$$3O_2 = 2O_3 - 59{,}200 \text{ calories.}$$

Ozone is therefore a very unstable body theoretically, and practically we find such a state to be the case. To work any one of the ozonizers economically in the laboratory the author has found it very convenient and satisfactory to first dry the oxygen or air by passing it through concentrated sulphuric acid, and then through a long tin or lead worm immersed in iced water. The chilled, dry oxygen of course gives the richest yield of ozone. A very efficient design of ozone generator, and one of easy manufacture in the laboratory is illustrated in connection with an induction coil in Fig. 8. This simply consists of a large outer glass tube of any length, containing a number of small, thin-walled glass tubes closed by sealing off at one end. Narrow strips of tinfoil are pushed into each tube as indicated and joined together in the manner of connecting up an electrical condenser. A stream of chilled, dry air or oxygen is passed through the large tube. Of course for a large outer tube of great length a very powerful induction coil must be employed. The adjustment of the size and length of tube to the induction coil, the temperature, dryness, and rate of supply of air or oxygen, etc., make a very valuable set of conditions for the student to experiment with with a view to obtaining a combination of maximum efficiency. The electrical energy supplied to the coil should of course be measured, as well as every other chargeable item in the production of the body in question. There are other ways of producing ozone electrically, although in point of efficiency they cannot be compared with such pieces of apparatus as described. Among the experiments in electrolysis yielding as one of the products ozone, may be mentioned the electrolysis of aqueous solutions of nitric acid, hydrofluoric acid, sulphuric acid, and phosphoric acid, as well as in solutions of potassium nitrate, potassium phosphate, and sodium sulphate. Hydrochloric, hydrobromic, or strong nitric acid do not produce ozone when electrolyzed. Neither do aqueous solutions of metallic chlorides, bromides, iodides, or ferrous sulphate. According to Houzean, the electrolysis of water furnishes only 3 to 5 milligrammes of ozone per liter. When a given quantity of oxygen is subjected to the action of charged surfaces as presented in any of the foregoing descriptions of ozonizers, only one-fifth, at most, according to Bloxam, is converted into ozone; but if the ozone be now removed by some substance which absorbs it, a fresh quantity of the oxygen may be ozonized. The proportion of ozone formed depends upon many conditions, the intensity and frequency of the electrical discharge, the pressure, quantity, temperature, etc. The question of temperature in all ozone processes appears to be by far the most important. According to the older researches, about the time of 1880, 20 per cent of the oxygen becomes ozone at —25 deg. C., and only 12 per cent at 20 deg. C., the ordinary working temperature of a chemical laboratory. At the temperature of boiling water, the production is but 2 per cent. In more recently made determinations, 1893, it is stated that the production is 5.2 per cent at 20 deg. C. The matter of ozone production has occupied the minds of many inventors during the last few years and many forms of commercial apparatus have been designed and constructed to produce this gas upon a very large scale. There are drum-shaped chambers containing many sets of stationary tinsel brushes arranged around the cylindrical interior, with corresponding revolving sets of brushes to constitute the opposite pole, for example. High potential discharges of varying current strength have been experimented with in such pieces of apparatus, and it has been found, to produce the best effects, that high potential difference with small current and energy value must be used. Probably this is due to the absence of heating effect with electrical discharges of small quantity. A thick heavy discharge appears to break up the ozone formed almost as rapidly as it is produced.

Commercial Production of Ozone and Its Applications.

Among the early plants for the commercial production of ozone for its practical application, may be mentioned two equipments in Germany, where ozone is used as a sterilizing and oxidizing agent in connection with commercial water works and supplies. These plants are situated in Schierstein, near Wiesbaden, and in Paderborn respectively. Ozone is well adapted for water sterilization and purification, being a powerful destructive agent to all organic matter both animal and vegetable. Of its efficiency there is no longer any

doubt, as experiments conducted over a long space of time all go to prove its great efficiency. The question lies in the cost entirely, and in order to secure figures of value upon this question we must study a commercial working equipment. The two German plants referred to were installed by the Siemens & Halske Company, of Berlin. The plant at Schierstein is designed to sterilize 66,000 gallons of water per hour as a maximum. This maximum output is called for only for occasions when exceptionally large quantities of water are required, while the average demands are about one-half of this, or 33,000 gallons per hour. This plant is divided into two independent units, like lighting and power units, the one being in operation while the other is at rest. The electrical generators installed furnish electricity for operating pumps for the air and water, and also for working the step-up transformers. These transformers receive the current at a pressure of 120 volts and supply a current from the secondary winding, at a pressure of 8,000 volts, the secondaries of course being connected with the ozone generators. The ozone produced by the action of this discharge is driven by fans into the sterilizing towers, in which the ozone rises and comes in contact with the water flowing down. The water is thus intimately mixed up with the gas and is thereby purified and flows off to a reservoir. In the ozonizer room there are 48 ozone generators mounted on stout shelves on both walls opposite an aisle, the battery being divided into two halves to be connected with the two generating units respectively. Each half, therefore, contains 24 ozone producers or generators, and these in turn are divided into three series, of 8 ozonizers each, and each series of eight is connected to the 8,000-volt secondary winding independently. We have, therefore, three sets of 8 ozonizers in series, connected in parallel to the secondary of the transformer. One series of eight ozone generators produces a sufficient quantity of ozone for one sterilization tower. The ozonizers are of the Siemens tube type, constructed of glass and metal, one pole being grounded on account of the method employed of cooling the inner tube with water. The connections to the positive pole, the pole which is not grounded, are well protected, so that it is not possible for the attendants to meet with accidents from the high potential. Eight ozonizing tubes or generators are contained in an iron box, the upper, lower, and front sides of which are provided with heavy glass windows. The ozonizer room is usually kept darkened, and the attendant whose duty it is to enter it sees at once from the blue light passing through the glass windows of the apparatus whether it is working satisfactorily or not. As all the metallic parts connected to the 8,000-volt poles are carefully protected on the one hand, and grounded on the other, there is little danger of a fatal accident. The sterilizing room in this plant contains two series, each of four towers, of brick. Each tower is divided into four sections by two partition walls perpendicular to one another. These towers are filled with a coarse gravel through which the water trickles on its downward flow, presenting a great surface to the action of the ascending ozone. Through the combined four sections of each tower, 11,100 gallons of water are flowing downward per hour, while in the same time 2,800 cubic feet of ozonized air pass upward through the gravel. For the operation of each half of the plant, sterilizing 33,000 gallons of water per hour, 50 horse-power are required, of which 27 horse-power are used for the ozonizers, 22 horse-power for the pumps, and 1 horse-power for various minor purposes. The cost of the process at Schierstein is 0.35 cent per cubic meter of water sterilized, 0.1 cent being the cost of the coal required for the operation of the ozonizing apparatus. To this must of course be added the usual interest on the money invested in the plant, and the cost of depreciation and repairs. This particular plant has to operate pumps in addition to its electrical apparatus, which is very unsual, and can be deducted from the cost in almost any other water works. Tests of the sterilized water, made by leading German chemists and bacteriologists, proved that the sterilization process by means of this apparatus is in every way successful so far as the annihilation of germs and bacteria is concerned. The process has therefore been shown to be well adapted to the purification of drinking water. The installation at Paderborn is similar to that at Schierstein, with the exception of the sterilizing towers. The purified water in this plant is allowed to flow off in the form of a cascade, in order that the contained ozone dissolved may be liberated and given off. The cost of purifying a cubic meter of water in this equipment is placed at 0.4 cent, including interest, depreciation, and wages, etc.

Apparatus has been designed and constructed, and tested at Niagara Falls in this country, using an electrical discharge under a potential difference of 50,000 volts as against the 8,000 employed at the German works. Ozone produced with this equipment was passed through two pipes to a water-sterilizing tower partly filled with cracked rock, one supply pipe entering the bottom and the other the top of the tower. The water flowing through the tower downward meets with the gas from all sides, above, and below, and is purified by its contact with the several ozone streams. It is claimed that 30 to 40 horse-power are sufficient to sterilize 6,000 tons of water daily. Some interesting experiments have been conducted by Warburg, who investigated the production of ozone by discharges in a closed volume of oxygen. In this case the formation of ozone has a limit which varies widely with the conditions of the experiment. Besides the ozonizing effect of the electrical discharges, there exists also a contrary effect which counterbalances the production after a time. Since for the limited duration of the ozonizing process the spontaneous decomposition of the ozone is negligible, it follows that the electric discharge itself must produce the contrary effect. In endeavoring to obtain a measure of both effects, Warburg starts from the assumption that the ozonizing effect is proportional to the number of molecules of oxygen present, while the decomposition is proportional to the number of ozone molecules present. There is a decided difference between the behavior of a positive discharge and that of a negative discharge; the maximum percentage of ozone, according to Warburg, is about three times as high for negative as it is for positive discharges. If after the negative maximum is reached, the mixture is subjected to the positive discharge, the percentage falls to the positive maximum. The decomposing activity is the same for positive and negative electricity, but the ozonizing action itself is three times higher for negative electricity. The effect of temperature upon both discharges is the same. The author has not verified these data, but introduces them as the work of a careful and reliable experimenter. If partly ozonized oxygen is left to itself, the proportion of ozone decreases according to Warburg, in an interesting manner for different conditions. This decrease is known under the name of spontaneous de-ozonization, and may be due to a great variety of causes. The experimenter referred to points out that since the amount of ozone at 200 deg. C. in a state of equilibrium is inappreciable, such equilibrium can be attained at ordinary temperatures only by complete dissociation of the ozone. The factors bringing about this dissociation may be external, as for instance, a contact with foreign bodies or with the walls of the vessel; or they may be internal and due to the collision of two molecules of ozone or of a molecule of ozone with a molecule of oxygen. Warburg formulates a mathematical theory of the process, and finds by suitable experiments that the internal effects are almost entirely due to collisions between the ozone molecules themselves. Heat increases this internal disintegration much more rapidly than it does the external process, and it becomes the chief agent at high temperatures. The experimenter in question finds that moisture makes no difference in the stability of ozone at 100 deg. The various forms of ozone generators suggested and in use to-day would fill a volume in themselves, and it is believed that the fundamental principles and typical forms introduced here will be a sufficient guide to the student who wishes to experiment with this interesting and valuable modified condition of oxygen. In the next chapter, which will appear in book form, published by the author, another gaseous product will be dealt with of no less scientific interest or technical value. This will pertain to the electrical production of nitric acid from the atmosphere. This is the last article to be published in the SCIENTIFIC AMERICAN SUPPLEMENT. Ten additional chapters on the practical side of electrochemistry will be added and published at once in book form. Those interested may correspond with the author direct at George Washington University, Washington, D. C.

EUPHORIMETRY; OR, THE ART OF MEASURING THE FERTILITY OF THE SOIL.

MANY chemists and many scientists have sought practical means for determining, in an indisputable and mathematical way, the fertilizing power of the soil. Thaer, in his "Guide pour l'Enseignement de l'Agriculture," seems to be the first who has occupied himself with this question. He expresses in these terms his right to the discovery of euphorimetry: "The means will be found some day of measuring with precision the productive power of the soil. If this discovery is not made during my life, at least I shall have contributed to bring it about."

Later, M. Varembey made a series of researches in this direction. His observations on manures and distribution of crops, their products and their action on the soil, deserve the attention of agriculturists, and we will refer to his experiments in this article.

The object of euphorimetry is to place agriculture in the rank of the exact sciences and to formulate fixed and positive rules, thus replacing tentative and irrational methods with a well-defined practical system. This object, we may venture to say, is not unattainable. For a long time chemistry, offspring of alchemy, was an art without principles; nevertheless it developed into a science of immutable laws, while often the original causes of the phenomena were not investigated. It recognized, for instance, that an acid unites with such and such a base in preference to another, and it thence deduced the law of elective affinities, without concerning itself with the inexplicable causes of such affinities.

To establish agricultural science it is not necessary to explore the cause or causes, yet unknown, of the productiveness of the soil. It suffices to state the fact, to take it as it is, and to study the reciprocal effects of the fecundity of the soil on vegetation and of vegetation on the fecundity of the soil. It remains to distinguish this fecundity, to ascertain what may augment or diminish its intensity, and to find the means of measuring it by its greater or less effects on vegetation. To succeed in defining the fertility of the soil and of expressing it in figures there is, of course, much to be done; nevertheless, it is possible to make a commencement with the data at hand.

The first necessity is to have a comparative type or standard. To measure heat, we have the degrees of the thermometer; weight, length, superficies, and volume can be ascertained by special methods of measurement; but the base for mathematical calculations of the fertility of the soil has not yet been discovered. Science has sought to explore this fertility by analyzing the soils chemically, and thus has ascertained the fertilizing elements contained in it, such as nitrogen, phosphoric acid and potash, and has indicated to agriculturists the fertilizing elements to be added for an advantageous harvest.

M. Varembey made a series of researches in this direction. His experiments on the science of euphorimetry deserve to be studied; they will enable us to make precise calculations. He operated with farm manure, and of course the same tests may be made with chemical fertilizers. He assumes as a principle that we cannot measure the fertility of the soil without choosing as a standard of measurement a substance endowed with a great power of fertilization and capable of being transported, divided, and employed in determined quantity. All things considered, farm manure responds conveniently to these conditions.

Chemistry may investigate the principles underlying its actions, but in euphorimetry positive results are examined, without reference to their causes. To determine the effect of a quantity of manure on a given superficies of land, and thus to establish scientifically the basis of fertility, a level field of four hectares, of which the soil is homogeneous and of average consistency, is divided into four parts of one hectare each, which we will designate by the numbers 1, 2, 3, 4. No. 1 does not receive manure; on No. 2, 10 cart-loads of partly decomposed manure, weighing 1,000 kilogrammes each, are deposited; 20 similar loads are spread on No. 3, and 30 on No. 4. The whole is plowed and sown the same day. At the harvest the products of the four hectares are reaped separately, threshed with care, and measured. If No. 1, which had not received manure, produces 7 hectoliters; if No. 2, which received 10 loads, produces 10.50 hectoliters; if No. 3, which received 20 loads, produces 14 hectoliters; and if No. 4, which received 30 loads, produces 17.50 hectoliters, it follows that every 10 loads augment the crop (which, unaided by manure, is 7 hectoliters) by 3.50 hectoliters, and that consequently each load augments it 35 liters.

Similar experiments made on rye, barley, and oats demonstrate that 1,000 kilogrammes of ordinary manure spread on one hectare increase on an average, the crop of rye, 35 liters; that of barley, 42 liters, and that of oats, 58 liters.

According to these indications, a standard of measurement of the fertility of soils may be established, by a euphorimetric scale from 1 degree to 10 degrees. Every degree of this scale would represent a degree of fertility equivalent to the effect of vegetation produced by 1,000 kilogrammes of manure on 1 hectare. Thus, we know that every degree of fertility found in the soil produces 35 liters of wheat per hectare, or 35 liters of rye, or 42 liters of barley, or 58 liters of oats. According to these preliminary data, it is seen that, when the number of degrees of fertility contained in a soil are known, it is very easy to determine what quantity of one of the cereals it will produce per hectare, and, *vice versa*, when the quantity of a harvested cereal is known, it is easy to determine the number of degrees of fertility contained in the soil that has produced it.

Example.—When it is known that the fertility of the soil is 45 degrees, and it is desired to ascertain how much wheat per hectare it will produce, these 45 degrees are multiplied by the produce of 1 degree, that is, 45×0.35 hectoliters $= 15.75$ hectoliters of wheat per hectare. For rye, barley, and oats the process is the same, taking as a basis the figures already given. Inversely, when it is known that a crop of wheat has produced, for instance, 14 hectoliters per hectare, and it is desired to know what was the degree of fertility of the soil that produced it, these 14 hectoliters are divided by the product of 1 degree, that is, $\frac{14}{0.35} = 40$ degrees of fertility. Later, it will be known how much fertility the harvest has abstracted, and consequently how much of it remains.

The following is the means by which nature can indicate how much fertility the cereals already mentioned abstract from the soil that bore them, and what the rate of diminution is in such case. After the harvest of the experimental field has been reaped, barley is sown in the spring in the four hectares without manure; it is reaped, threshed, and the produce of the four numbers are measured separately. If No. 1, which had not been manured for the wheat, produces 5.04 hectoliters of barley; if No. 2, which had been fertilized with 10 cartloads for the wheat, produces 7.56 hectoliters of barley; if No. 3, which had received 20 loads for the wheat, produces 10 hectoliters of barley; and if No. 4, to which 30 loads had been applied for the wheat, produces 12.6 hectoliters of barley, it must be concluded that the fertility communicated to the soil by the manure had not been quite consumed by the wheat, but that the wheat left behind it a percentage of fertility, and this is now to be determined.

The fertility of hectare No. 2 was augmented 10 degrees by 10 loads of manure applied at the sowing of the wheat. If this had consumed none of the fertility, the crop of barley that succeeded would have been as abundant as if it had received the manure directly; consequently, for 10 whole degrees of fertility it would have produced 4.20 hectoliters more than what No. 1 produced, which had not been fertilized; but as it exceeded this by only 2.52 hectoliters, it follows that the difference, which is 1.68 hectoliter, is to be attributed

to the consumption of fertility by the wheat crop. The wheat therefore absorbed a quantity of 1.68 out of 4.20; now, 1.68 is to 4.20 as 40 is to 100; therefore the wheat absorbed 40 per cent of the fertility of the soil. The produce in barley of Nos. 3 and 4, which had been fertilized for the wheat, compared with that of No. 1, which had not been fertilized, give absolutely the same results, which have been invariably noted under similar circumstances. It must therefore be concluded that the exhaustion by the wheat is 40 per cent. The same test was applied to the other cereals. Rye was sown under the same conditions as those for the wheat and afterward oats without manure; it was proved thereby that rye absorbs 30 per cent of the fertility; by sowing oats after the barley and by comparing the two crops, as was done for the wheat and the rye, it was proved that barley abstracts 25 per cent of fertility.

The experiments of M. Varembey were not confined to farm manure; conclusions were drawn also from the various fertilizers and succession of crops. These are agents of fertilization that play an important part in agriculture, but it is difficult within the limits of an article like this to enter into details, and we will content ourselves with pointing out the services that researches in euphorimetry may render, both from a scientific and from a practical standpoint.

It may be objected in regard to the data already given that the inconstancy of the seasons and the variations of temperature may baffle all prevision and nullify all calculation. True, the value of the crop may be thereby affected, but in no way can they invalidate the exactness of the theoretical results of the fertility which it may be desired to compare. Therefore, whatever may happen, the cultivator, who puts into his soil farm manure, or any equivalent, may confidently say: "I am putting into the business materials for making in a few years all that may be produced out of wheat, or barley, or rye, or oats, with given degrees of fertility. Now, as I have added to the soil these degrees over and above what it could produce from its own resources, I should harvest so much wheat, so much of any other cereal. Nature will fashion these; temperature may occasionally interfere with the working of the machine, and some irregularities may occur in the annual output; but it is only a question of time and it is not the less certain that this quantum of fertility will be entirely recovered in wheat, barley, rye, and oats."

It may also be said that the foregoing estimations are either too high or too low. The objection would be groundless, for even were they hypothetical, and merely the ordinary relations which quantity bears to quantity, they would not the less demonstrate the usefulness of euphorimetry. These estimations are valuable means of comparison and the deviations, even were they considerable, would not change the quantities to which they are applied, nor, consequently, the exactness of the resultant comparison, for the relation of one produce to another produce would always be faithfully represented, since this relation can not by any means be changed, when the same variation applies simultaneously to both terms of a proportion.

Similar observations and calculations made on rye or barley, sown after oats, show that the exhaustion superinduced by the oats also amounts to 25 per cent.

Since these various cereals absorb only a known part of the degree of fertility, it is easy to determine how much wheat, rye, barley, or oats per hectare a full degree absorbs. For wheat, we calculate as follows: If 40 per cent of a degree of fertility produces 35 liters, how much will 1 degree produce? The answer is, 875 liters. Reckoning in the same way for the other cereals, we find that a degree of fertility gives for rye, 1.667 hectoliters; for barley, 1.664 hectoliters; and for oats, 2.336 hectoliters. Now we may also determine how much fertility a hectoliter of wheat, barley, rye, or oats per hectare has abstracted from the soil that has produced it. For the wheat we state thus: If 875 liters absorb 1 degree, how much does a hectoliter absorb? The answer is, 1.143 deg. Pursuing the same method with the other cereals, we find that rye absorbs 8.57 deg., barley 600 deg., and oats 428 deg.

Proceeding thus mathematically from the known to the unknown, the number of degrees of fertility found in any soil under cultivation may be ascertained when the amount of its last crop of cereals is known. Let us suppose, for instance, that we have to measure the fertility of a soil that has produced 20.40 hectoliters of oats per hectare as a last crop. If 1 hectoliter of oats abstract 0.428 deg., how much will 20.40 hectoliters abstract? 8.73 deg. But oats absorbs only 25 per cent of the soil fertility; therefore we state: If 25 deg. are absorbed from 100 deg., from how much are 8.73 deg. absorbed? 34.92 deg. And the crop having absorbed 8.73 deg., the remainder is 26.19 deg. Or course the same calculation will be made for the other cereals forming the test harvest.

The application of euphorimetry combined with the data of the Wolff tables, which show the average composition of the crops, may give most important material for making an exact science of agriculture, all the more as the tests we have spoken of in this article can now be made with chemical fertilizers, and also with the new methods of succession of crops and advanced methods of cultivation.

It is desirable to pursue such experiments, that our agriculturists may see the profit and advantages to result in the future from the application of the principles of euphorimetry. This is our purpose in presenting the subject. The science of which we have spoken is too little known; we have not found mention of it in any agricultural work and the dictionaries are equally silent.—Translated from La Nature.

SCIENCE NOTES.

That botany has a definite practical field aside from distinguishing deadly from edible mushrooms, or being able to tell poison ivy when you see it, is usually something entirely new to that most impractical of persons, the so-called practical man, and the assertion that years spent in looking through the microscope or in the scientific investigation of problems concerning plants could ever add to the world's wealth or be classed as a productive pursuit, is often quite beyond his comprehension. Because botanists generally want the interest of this class of men, would like their advice occasionally, and under all circumstances need their money, it is well perhaps that now and then the utilitarian side of the study of plants be emphasized, even though it may shock a few of those who seem to have associated themselves with the profession because they consider it so absolutely incapable of being turned to account. For it must be confessed that there still persists a small class of botanists who look upon anything practical connected with the subject in much the same way that a physician regards advertising.

Messrs. Chabrié and Bouchonnet have succeeded in preparing the fluorides of indium and rubidium. To prepare the fluoride of indium the hydrate is used as a base. It is formed by the action of ammonia on chloride of indium. The hydrate is then dissolved in a platinum capsule by hydrofluoric acid. When the solution is evaporated it deposits a white crystalline mass of hydrated fluoride of indium. This compound has the form of needles about 0.2 inch long of a white color, slightly soluble in water and insoluble in alcohol and ether. Hydrochloric and nitric acids dissolve it easily. When boiled with water and then left standing a white mass is deposited and the water takes an acid reaction. There is a dissociation in this case. The new compound gives off acid fumes in the air and attacks the vessels which contain it. When heated to redness in a platinum crucible covered with a watch-glass the latter is found to be attacked, and the crucible contains a powder consisting of sesquioxide of indium. The formula for the fluoride is In_2F_6, $18H_2O$. The second body, the fluoride of rubidium, is formed by mixing neutral carbonate of rubidium in solution by dropping into hydrofluoric acid. This gives a solution of fluorhydrate of fluoride of rubidium. By evaporating, concave or flat crystals are obtained. These are very deliquescent and are insoluble in alcohol and ether. They are obtained anhydrous only by placing them for a long time *in vacuo* over sulphuric acid. The formula for this body is RbF.HF. If the anhydrous fluoride is heated with fluorhydrate of ammonium in great excess a residue consisting of a white mass is obtained, whose composition is near that of the fluoride RbF, but does not exactly correspond to it.

Many skin diseases have yielded to treatment with the X-rays. To quote from a recent address by Dr. Holland: "In large numbers of skin diseases—acne, favus, ring-worm, sycosis, eczema, psoriasis, and others (I do not intend this to be a complete list) X-rays have proved useful. They have also been used for the removal of superfluous hairs, for the treatment of trachoma, and so on. But the three diseases which are the most interesting from this point of view are lupus, rodent ulcer, and malignant disease other than rodent ulcer. . . . In 1898 I had the pleasure of recording the first successful case of the treatment of lupus by X-rays in this country, and the patient at the present time, except for two slight relapses rapidly cured, remains well. . . . In the treatment of lupus generally, my opinion is in favor of the X-rays as against the Finsen light or any of its modifications. This means, I take it, that in my hands the treatment by X-rays has appeared to me to give better results. Certain advantages are obvious: X-rays are easier of application and more comfortable to the patient; the treatment, as a rule, extends over a shorter time; the whole area can be treated at each sitting; X-rays can reach a part where it is difficult or impossible to apply the Finsen treatment. As against these advantages one may say there is the risk of an X-ray burn; but I would put this entirely on one side, providing that proper care is used. Like all treatments, X-rays are not infallible, but I have never yet seen methodical and properly carried out X-ray treatment fail to produce a favorable effect in any case of lupus. In rodent ulcer, as we all know, the effect of X-rays is marvelous. The only question that has to be decided is that between X-rays and operation. This does not come in when the case has gone too far for the surgeon's knife, but the remarkable success of X-rays, even in these cases, compels one strongly to the idea that when we understand better the technique of X-ray application, this treatment may take the place of the knife in all cases.

M. Berthelot, in a paper read before the Académie des Sciences, gives an account of an examination he recently made of some samples of metal from ancient Egypt. Some of these were sent to Paris by Prof. Maspero and came from a tomb which he opened not long ago. The tomb is probably of the end of the second dynasty or the beginning of the third. The specimens have the form of debris of thin metal strips, formed of an alloy of copper, which is mostly transformed into oxychloride and carbonate, and mixed with crumbling limestone. The decomposition was so far advanced that it was impossible to separate the metallic alloy proper from its coating. An analysis made upon small quantities of the matter gave 56.7 per cent copper and 2 per cent tin. There were also traces of zinc, and in the coating was found a considerable proportion of chlorine, carbonic acid, oxygen, and lime, but no arsenic, lead, silver, or iron, at least in any great measure. This specimen is of interest from its great antiquity, as it goes back to the most remote epochs of the ancient empire. The presence of small quantities of tin at this epoch is remarkable. This metal no doubt comes from the voluntary addition of a tin-bearing mineral to the copper ore. As to the oxychloride and the carbonate of copper, these have been formed in the course of centuries by the slow action of mineral waters and air upon the primitive metal. The second specimen which M. Berthelot examined was an ingot of copper from the Louvre which he had loaned to him. The ingot came from Mariette's excavations at Sakkarah. It belongs to the epoch of the Pharaohs, and its general form is like that of the piled-up ingots which figure in some of the hieroglyphic inscriptions. The piece has a weight of 360 grammes. It appears like a plate which has been cast in a rough mold and measures 6 inches long and 2 by 0.3 inches section. The metal is covered with a slight greenish coating and where it has been rubbed off the metal appears red and bright. The coating is not uniform in appearance and has several distinct regions running parallel to the width. These no doubt come from the piling up of the ingots upon each other. According to analysis, the specimen is a bronze, with the following composition: Copper, 87.44; tin, 11.47; traces of lead, etc., 1.09 per cent. Only slight traces of other metals were found.

ELECTRICAL NOTES.

It is with reluctance that telephone and telegraph companies put their wires underground in cities, but this does not arise altogether because of the cost. Although the cost is heavy, the freedom from interruption of the service because of storms, fires, and other accidents to which overhead wires are subject largely compensates for it. The chief difficulty lies in the extraordinary increase in the induction of an underground cable as compared with a line wire. It is stated that one mile of underground wire has as great an effect in cutting down the effective transmission as 20 to 25 miles of overhead wire, and that 15 miles of underground circuits in New York city cuts down the current as much as over 800 miles of overhead circuits. In other words, it requires as much energy to transmit the current through 15 miles of underground circuit in New York city as from New York to Chicago by the overhead wires.—Machinery.

We are indebted to Popular Mechanics for the description of a portable home-made planer, built by an electric railway company in California which had occasion to plane several hundred wooden trolley poles, and found it difficult and expensive to haul the poles to a mill. This consisted of a planer head mounted on a substantial wooden truck and belt-driven by a 5-horse-power 500-volt direct-current General Electric motor. The rollers were made of two sections of 10-inch wrought-iron pipe, castings being fitted in the ends for the axle bearings. A pair of plow handles were used to push and guide the planer, the starting box for the motor being mounted between the handles. The entire outfit cost but $60 outside of the motor, which the company had in stock. The poles were 35 feet in length, with 8-inch tops, and it took about one minute to plane down one of the four sides of a pole. The poles were planed as they were unloaded from the cars, at the rate of six poles an hour. There was not only considerable saving in time, but also a great saving in expense, as it cost but ten cents per pole as against $1.15, the price estimated for doing it by hand.

The subject of conductors for protecting buildings from lightning is one upon which there is much misinformation, says Machinery, and it appears exceedingly difficult to discover just what position the lightning conductor occupies as a protector of property. Lightning rod agents have played upon the credulity of the public to such an extent that many scientific men have declared that lightning rods are of little or no use whatever. On the other hand it is conceded by others equally well-informed that when properly put up, the lightning rod is a valuable protector of buildings and tall structures, especially brick chimneys. According to Sir Oliver Lodge, who recently delivered an interesting lecture on the subject in Birmingham, an error that is frequently made in the installation of lightning rods is in using rods of too large cross section and of too high conductivity. He says that a copper rod is not as good as an iron rod, for the reason that a heavy copper rod lets down a current too quickly and produces a shock or collision because of the electric inertia or inductive effect; where a copper rod, say, a foot thick would be highly dangerous as a lightning conductor, an iron wire one-tenth inch diameter might be quite safe and effective. A heavy copper conductor is liable to side flashes, but a light iron wire allows the flash to leak down, as it were, and perhaps fuse it with little perceptible disturbance. A number of conductors are better than one, and are better when made of light iron wire than of heavy copper rod. Small iron wire may be fused and destroyed, it is true, but this contingency must be met by renewal. In fact the practice advocated would be very similar to the renewal of electric fuses, and the iron conductor and the fuse might be said to occupy analogous positions. When the fuse blows we expect to renew it, and the same holds true with the small iron lightning conductor.

ENGINEERING NOTES.

A record of the traffic on the Brooklyn Bridge for the last twelve months, kept by Bridge Commissioner Best, shows that about 36,000 passengers now cross the bridge in trains in a single hour at night. This means that the cars, which seat about forty people, actually carry about three times that number during the busiest hour, which is from 5:30 to 6:30 P. M.

According to the Electrical Review, of London, the Great Northern Railway of England has been experimenting with gasoline motive power for suburban traffic. The motive power is generated by two Daimler gas engines of 36 horse-power each. These engines drive onto a common longitudinal shaft which is connected to the two axles of the car by beveled gearing. To overcome the difficulty of one axle overrunning the other, owing to any possible inequality in the diameter of the wheels or for other reasons, a special form of differential gear is introduced, combined with which is the reversing mechanism. The engines are connected through independent clutches to a common change speed box, from which the power is transmitted through the longitudinal shaft to gear boxes suspended on each axle, from which point the speed is reduced by means of single reduction gearing. A separate gasoline tank is provided for each engine, and the combined capacity of these is sufficient for 400 car-miles. The car is lighted by electricity obtained from storage batteries, which also supply energy for ignition and for the magnetic clutches. The weight of the car, including passengers, is 16 tons, and it is designed for a speed of 30 miles per hour, although it has on several occasions surpassed a speed of 50 miles.

A very remarkable railway accident in which a locomotive and a train of loaded 100,000-pound ore cars jumped off the end of a high switchback and cleared a distance of over 300 feet before striking the ground, is described in the Engineering News. This is doubtless the record "long jump" for a railway train, and will match the most thrilling romances of imaginative story writers in which locomotives have been made to jump across the gap left by a missing bridge or trestle. On its face, the accident would appear to have been a needless one. The runaway was caused, according to the statement furnished, by the sticking of the throttle valve on the locomotive. Of course the brakes would not hold the train on a 4 per cent grade with the locomotive working steam; but one wonders why the reverse-lever was not used. By throwing it into mid-gear or a little back of the center the engineer should have been able to stop his train with the brakes. It hardly seems possible that both the throttle and reverse lever could have gone wrong at the same time. It is true that on heavy locomotives with slide-valves the reverse lever is hard to move when the engine is working steam; but the engineer and fireman together should certainly have been able to pull the lever back. The accident gives a hint, also, why a locating engineer always tries to end a switchback stub-end on a steep up-grade. To run out the end of a switchback on a high embankment may have been a necessity in this case, but such a location at the foot of a long, steep mountain grade is a standing menace whenever from any cause a train exceeds a given limit of speed down the grade.

According to the Mechanical Engineer the erection of the first installment of the Mond gas-producing works at Dudley Port, Tipton, is now practically completed, and it is expected that a supply of the motive power for industrial purposes will shortly be available. The works constitute a pioneer scheme in this country, and when completed will be the greatest gas-producing and distributing plant in the world. The plant, which is the first of four units, has already been tested with highly-successful results. It consists of eight producers with all their attendant regenerators, blowers, pumps, washers, acid tower, gas-cooling and air-heating towers, sulphate plant, etc. For the purposes of raising steam there are four large water-tube boilers, which are capable of being used either with solid fuel with a natural or forced draught, or with gas fired automatically, and will raise steam with extreme rapidity. There are three pairs of very powerful compressing engines for forcing the gas through the distribution mains. These engines, which are fitted with all the latest improvements, are capable of compressing the gas to 10 pounds per square inch above atmosphere. Much of the producer plant has been erected in duplicate, so as to avoid all stoppages which might otherwise occur when portions of the plant have to be cleaned. Some idea of the dimensions of this single plant may be realized from the fact that it is capable of manufacturing a million cubic feet of gas per hour, and of distributing it through the main at that rate. The ability of the compressing engines to distribute it at that rate was proved only a few days ago, when one million cubic feet of air were forced through five miles of main. The result of this experiment is important, as it effectually dispels the doubt which was at one time raised in some quarters as to the ability to distribute the gas at sufficient pressure at long distances from the station. It is calculated that the four units comprising the contemplated complete plant will be capable of producing twenty-five thousand million cubic feet per annum.

It seems reasonable to suppose that the total amount of water power actually used for electrical production throughout the world at the present time must exceed 2,000,000 horse-power.

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